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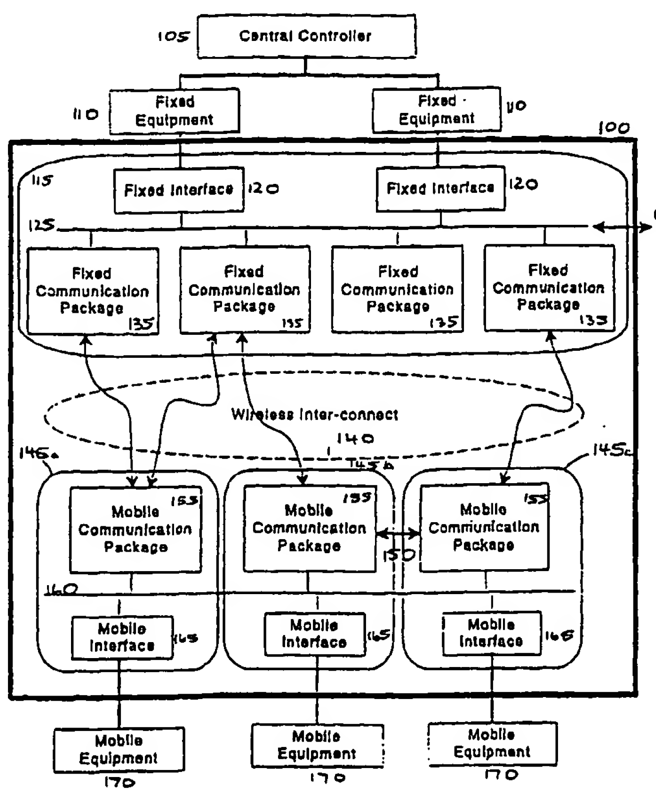
(54) Title: COMMUNICATION SYSTEM FOR MOBILE NETWORKS

(57) Abstract

The present invention provides a communication system for mobile networks. At the highest level of organization, the system, termed a Communication System for Mobile Networks (CSMN), comprises four components: 1) one or more fixed networks; 2) one or more mobile networks; 3) wireless inter-connecting means; and 4) open standards-based protocol means throughout the system. One generalized embodiment of the CSMN system, termed a Mobile Network Vehicle System (MNVS) comprises: 1) one or more surface-level networks; 2) one or more on-board vehicle networks; 3) radio frequency data links; and 4) open standards-based protocol means throughout the system. One specific embodiment of the MNVS, termed a Communications Based Train Control (CBTC) system comprises: 1) one or more wayside networks; 2) one or more carborne networks; 3) radio-frequency data links; and 4) a standard internet protocol means throughout the system. In a preferred embodiment of the CBTC system, the transceivers employ 2.4 GHz Hybrid Spread Spectrum radio transceivers which employ both Slow Frequency Hopping and Direct Sequence Spreading Techniques, in addition to a half-duplex Time Division Multiple Access scheme which allows one wayside spread spectrum transceiver to communicate with many carborne spread spectrum transceivers at one time.



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COMMUNICATION SYSTEM FOR MOBILE NETWORKS

BACKGROUND OF THE INVENTION

Due to the growth in the use of cellular technology, primarily telephones and personal computers, development of the technology supporting mobile communications networks has burgeoned. Thus, in the cellular communications field, it has become increasingly important to be able to determine the position of mobile radio terminals. Many patents have been issued for technology relating to mobile terminal position determinations using a fixed network system with multiple mobile units.

Mobile Communication Units

One example is U.S. Patent No. 5,969,678 issued to Stewart which provides a geographically based communications service system comprising a mobile unit for transmitting and receiving information, and access points connected to a network. The access points are arranged in known geographic locations and transmit and receive information from the mobile unit. When one of the access points detects the presence of the mobile unit, it sends a signal to the network indicating the location of the mobile unit and the information requested by the mobile unit. Based on the signal received from the access point, the network communicates with information providers connected to the network and provides data to the mobile unit through the access point corresponding to the location of the mobile unit.

In another example, U.S. Patent No. 5,968,123 issued to Fujiwara and Shimizu provides a method for controlling the position of a mobile host in a local area network (LAN), whereby the movement of the mobile host out of a certain LAN can be quickly detected even when the mobile host transmits no frames and invalid traffic can be reduced.

In yet another example, PCT Application No. PCT/US96/03797 to Ghosh, Reed, Rozanski and Buford ("Ghosh") discloses a method and system for determining the position of a mobile terminal in a Code Division Multiple Access (CDMA) communications system (e.g., in accordance with the IS-95 standard). Triangulation is used to determine the mobile terminal's position.

PCT Application No. PCT/SE97/00219 to Ekman, Hedlund, Lundqvist and Ghisler ("Ekman") discloses a method and apparatus for determining the position of a mobile terminal in an unsynchronized environment (e.g. without using an exact time reference). Instead, a plurality of fixed location reference radio terminals whose positions are known are used to make downlink propagation time measurements. The relative transmission time offset between base stations is determined and used to derive the position of the mobile terminal.

PCT Application No. PCT/SE96/03561-3 discloses a method and apparatus for determining the position of a mobile terminal in a cellular mobile radio system such as, for example, the Global System for Mobile Communications (GSM).

One example of the use of cellular radio systems comprising vehicle mobile elements, as opposed to communication elements (i.e., telephones and computers), is the use for train communications. Such a train radio system and such a mobile station are known from DE 42 22 237 A1 issued to Hupperich and Weis ("Hupperich"). The respective train radio system is described as a cellular radio system for a train radio, wherein adjacent radio stations use different radio frequencies, such that a number of radio cells are aligned in the form of a radio-cell chain along the route. The therein-described mobile station inside the vehicle (train) is connected to that radio station in whose radio cell it is located. As described in the Hupperich patent, to realize the train radio system in a simple manner, it is designed in accordance with the GSM standard. A control device, which is connected to the radio stations, controls the establishment of a radio link from one radio cell to another while the train is traveling.

United States Patent No. 5,937,350 issued to Frank provides a train radio system with a simple network structure that is suitable for a safe radio transmission. The train radio system comprises radio stations, which are arranged along a route, and a mobile station, mounted in a vehicle moving along the route which comprises a transceiver and a data bank connected thereto, into which identification codes for the radio stations can be entered.

Other systems have been developed to address the issue of mobile data communications but these tend to focus on the communications between a fixed network and a mobile device that has a network address. Examples include the cellular phone or the various mobile IP protocols. In most cases the mobile device is assigned different network addresses at different times.

Some of the fundamental mobile IP work was disclosed in United States Patent No. 5,159,592 issued to Perkins ("Perkins"). The Perkins invention is a method and apparatus for managing transmission of information between a fixed wired network and at least one mobile communication unit in wireless communication. The wired network is of the type wherein users of the network are each assigned a unique network address such as in, for example, a TCP/IP network. Designed for individual users with portable and handheld computers, for which the movement about the network is typically the rule rather than the exception, this invention is limited to coupling wireless migrating individuals to a network operating in accordance with the TCP/IP type-protocol.

In each of the above-mentioned cases, the mobile units are singular units communicating with a fixed network. In contrast, the present invention provides a network of mobile units communicating with a fixed network. The mobile units form a network due to the need to monitor their position relative to one another within the network environment or system. In the present case, it is neither practical nor desirable to reassign the network address as the mobile network moves. Thus, the problem of maintaining reliable continuous communications between endpoints where the interconnections of the networks are changing rapidly has been overcome.

Application to Mass Transit Systems

One example of a mobile network is an urban mass transit system that can carry persons, goods and/or materials from one station to another. Existing, discontinuous transport systems of public conveyance, such as railroad trains, streetcars, monorails, subways, automobiles,

etc. provide a mode of transportation that requires positional monitoring capability. Because trains share a common track system, there is a requirement for relative positional monitoring.

Historically, train and transit operators have utilized a signaling architecture known as a "fixed block" where trains are physically signaled from fixed posts along the wayside as to whether or not they are authorized to enter the next block of track. If there is another train in the next block of track, the signal will be red, indicating that the train must stop until signaled that the block is cleared. The fixed blocks vary in length from hundreds of yards to tens and even hundreds of miles. Virtually all of these signal and train control systems use track circuits for train detection.

Track circuits served the rail industry well for more than 100 years. But as heavy steam trains gave way to light rail systems and DC and AC propulsion it became increasingly difficult to make track circuit-based systems work reliably.

All track circuit-based systems are designed to be "failsafe" and as a consequence of traditional signal design, nearly all are "fail stop". This means that when they fail safely these systems present a more restrictive aspect (usually red) to the operator or on-board train control system. For smaller systems with few track circuits, or systems with long headways, fail stop may be an infrequent annoyance. In the case of larger transit systems, however, fail stop can mean frequent operational disasters that are expensive and time consuming to mitigate.

In order to address the obvious deficiencies of fixed block signaling, train and transit operators have been seeking ways to implement "moving block" signaling. Instead of controlling train separation by regulating movement past fixed points along the wayside (i.e., into fixed blocks of track), moving block signaling regulates the actual separation, or distance, between trains. The key to moving block signaling is that the trains must have uninterrupted radio communication amongst themselves and to the wayside in order to pinpoint exact locations and receive control messages. This has proven to be a major challenge, due to the train environment, which is very radio hostile due to, for example, large amounts of metal, tunnels etc. that tend to interfere with radio signals.

There are a number of U.S. and Canadian patents that are illustrative of prior art. In one example of mass transit train systems, US Patent No. 5,757,291 issued to Kull discloses a self-contained anti-collision system that does not require a central controller. The invention adds a receiver, computer, modem and global positioning system (GPS) receiver to the locomotive control unit already installed on trains. The system coordinates messages received from other nearby trains and transmits information to said trains on a common radio frequency including train location, speed, identification and direction. In this invention, trains communicate directly with other nearby trains using a common radio frequency to warn them of the likelihood of collision.

US Patent No. 5,751,569 issued to Metel and Pretorius eliminates the need for a central controller. The invention is a method of controlling railroad train movement wherein objects such as signals, track block and switches located within a given zone communicate only with the neighboring zone using predetermined messages. The signal is not further defined. There is only communication between adjacent geographic control units. This invention is problematic in that the communication will only be in one of a defined series of predetermined messages (ie: lock request, lock grant, protect request, protect grant, etc.).

In US Patent No. 5,398,894 issued to Pascoe, a moving block train control system is disclosed, which purports to overcome the reliance on a central control facility. When a train enters a zone, the wayside control unit sends a signal to it, presumably to identify the zone entrance. Once the train receives the signal, it can track itself within the zone using a tachometer. The train periodically transmits its location to wayside equipment. Monitoring the location of trains within a zone, the wayside unit can transmit interlocking equipment information to these trains. The invention discloses the creation of virtual track circuits or blocks with each zone. The wayside control units determine whether these virtual track circuits are occupied or not.

US Patent No. 4,711,418 to Aver, Jr. and Petit, discloses a railway signaling and traffic control system. Trains send and receive radio signals from a central office. The signal transmitted by the train identifies said train and its location in a specific zone, and it may also include a voice communication request, emergency condition message and track switch condition messages. Passive transponders are located at the limits of zone boundaries. When

the train exits one zone and enters another, it passes by a transponder, which transmits the signal to a central office. Both the central office and the trains can generate multibit digital words that can be transmitted by radio. The invention uses a radio communication and position locating system instead of track signals for route requests and train location. The transponders replace pole lines for power and communications.

Canadian Patent No. 1,045,237 to Sibley discloses an improved train control system that detects, decodes and responds to coded track signal emitted by wayside stations. The track signal is an alternative current (AC) signal of constant frequency. The track signal code rate is determined by measuring the number of cycles of a higher frequency, which accompanies said track signal. At the end of one cycle, a particular "flip flop" is determined. This flip flop is indicative of the track signal code rate. When the flip flop (and thus the track signal) is detected, a vital relay is actuated. When the vital relay is actuated the light on the track changes from green to red. This invention eliminates the need for bulky and expensive filters and/or tuned circuits on the train.

In spite of the above described systems, there remains a need for a mobile network communication system that is accurate, fast, inexpensive, less susceptible to physical damage and that can operate in a truly wireless format in a hostile environment. This communication system can be used with train systems, mass transit systems or other systems where it is necessary or desirable to connect one or more mobile networks in a wireless format to one or more fixed networks for the purpose of communication.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a depicts one embodiment of the CSMN. The system in this example contains one fixed network, a wireless inter-connect and three mobile networks. Other embodiments could have one or more fixed networks and one or more mobile networks.

Figure 1b shows an example of the fixed network **115** for the CSMN comprising the wireless interconnect **130** which shows connections to other fixed networks, the network interface and protocol conversion **175**, standard IP router **180**, wireless controller **184**, wireless modem **186**, and connections to fixed equipment **110**.

Figure 1c shows an example of the mobile network **145** for the CSMN comprising network interface and protocol conversion **188**, standard IP router **190**, wireless controller **192**, wireless modem **194**, mobile communication package **155**, mobile network interface **142**, and connections to mobile equipment **170**.

Figure 2 depicts one embodiment of the CBTC system.

Figure 3 shows a breakdown of the system architecture of one embodiment.

Figure 4 shows a WRF network that uses Class A IP addresses.

Figure 5 illustrates a carborne network that uses Class A IP addresses.

Figure 6 portrays a TDMA scheme, corresponding to wayside transmission during the first half of the frame and carborne transmission during the second half of the frame.

Figure 7 shows one example of the radio transceiver, consisting of six functional blocks.

Figure 8 shows one embodiment depicting how information is digitized.

Figure 9 portrays the down-conversion of a received signal to the base-band.

Figure 10 is an example of pseudo-randomly chosen, uncorrelated frequency sequences.

SUMMARY OF INVENTION

The present invention provides a communication system for mobile networks. At the highest level of organization, the system, termed a Communication System for Mobile Networks (CSMN), comprises four components: 1) one or more fixed networks; 2) one or more mobile networks; 3) wireless inter-connecting means; and 4) open standards-based protocol means throughout the system.

The present invention also provides one generalized embodiment of the CSMN system, termed a Mobile Network Vehicle System (MNVS), which comprises: 1) one or more surface-level networks; 2) one or more on-board vehicle networks; 3) radio frequency data links; and 4) open standards-based protocol means throughout the system.

The invention also provides one specific embodiment of the MNVS system, termed a Communications Based Train Control (CBTC) system, which comprises: 1) one or more wayside networks; 2) one or more carborne networks; 3) radio frequency data links; and 4) a standard internet protocol means throughout the system.

DETAILED DESCRIPTION OF THE INVENTION

As employed throughout the disclosure, the following terms, unless otherwise indicated, shall be understood to have the following meanings.

The term, "acquisition" is used to denote a process wherein each radio transceiver located on a vehicle unit attempts to become a member of an RF communication cell.

The phrase, "active redundancy" refers to having a live redundant network with the characteristic that a failure of some component will simply cause its redundant, already active component to take over the load.

The term, "availability" is defined to be the percentage of time that an entity is performing its required functions at or above the specified performance level. Typically, availability is specified in units such as the Mean Time Before Functional Failure.

The phrase, "backup redundancy" refers to having a live component being monitored by an equivalent unit which can take over if it detects a failure. The backup unit will be "warm", in the sense that no startup is required prior to it taking control, but it will not be actively participating in the network.

The term, "car" is used to denote the moving vehicle component of a system. It will be used to represent, for example, a train car, bus, trolley car, subway train car, or other passenger

and/or cargo transportation means such as for a mine car or freight train, which repetitively moves within a network or system. The term "car" is used interchangeably with the term, "vehicle."

The term, "carborne" is used to denote the equipment (hardware and/or software) that is physically located on a mobile unit such as a car or vehicle in the mobile system, i.e., the train, trolley car, subway-train, etc. This term is used interchangeably with the term "vehicle-borne".

The phrase, "Carborne Interface Unit (CIU)" is used to denote the unit that connects the on-board vehicle controller to the CBTC IP network.

The phrase, "Carborne Radio Frequency (CRF)" unit is used to denote the device on the train, consisting of an IP router and a radio modem that connects the carborne network to the wayside network.

The phrase, "CBTC Operations Protocol (COP)" is used to denote the operations protocol between CBTC routers.

The term, "cell" is defined to be a dynamic area within which radio frequency communication between a surface-level transceiver and one or more on-board vehicle transceivers is possible.

The term, "chip" is used to denote a single bit sent over the radio link. In Direct Sequence Spread Spectrum radio, each bit of data is sent as a sequence of chips. In one embodiment of the CBTC system, there are 31 chips per bit of data, and 63 chips per bit of control information.

The phrase, "Code Division Multiple Access (CDMA)" is used to denote a technique used in Spread Spectrum radio to create multiple channels using the same frequency band by coding each one with a different spreading code (see DS).

The term, “consist” is used to denote the coupling of two or more units, i.e. when two or more units are coupled, they form a consist.

The term “Direct Sequence Spread Spectrum (DS)” is used to denote the technique of transmitting each bit of data as a pseudo-random sequence of “chips”. This has the effect of spreading the band over which the signal is transmitted by a factor corresponding to the number of chips per bit.

The phrase, “Dynamic Channel Selection (DCS)” is used to denote the process by which the mobile radio keeps track of multiple frequency hopping sequences - or channels - at a time, and reports a figure of merit for each.

The term, “failover” is defined as the act as transferring some of the functionality from the active device to its redundant counterpart, the backup device. This may be done implicitly, such as when rerouting around failed links, or explicitly, such as when switching which WRF controls the radio link. Failover must be transparent to the communication system.

The phrase, “failover API (FAPI)” is used to denote the set of functions available to all the software components to provide the redundancy capabilities, and will also refer to the central task which may exist to handle the failover and fault reporting.

The term, “fault” is defined as a failure of some individual component or functionality. The system is designed to be fault-tolerant, so it will continue to operate (not fail) in the presence of a small number of faults.

The phrase, “Forward Error Correction (FEC)” is used to denote a sequence of data bytes computed from a packet of data to be transmitted in order that, using this data, certain errors in transmission may be corrected at the receiver. Reed-Solomon encoding is an example of forward error correction.

The term, “fragment” is used to denote small pieces of internet protocol packets, i.e. in order to transfer internet protocol packets over the radio link, it is necessary to break them into smaller pieces, these pieces are called fragments.

The term, "frame" is used to denote one complete cycle of transmit and receive time slots on the radio. During one frame, it is expected that each train receives one message from the wayside and transmit one message to the wayside.

The phrase, "Frequency Division Multiple Access (FDMA)" is used to denote a technique used in radio to create multiple channels by having each one use a different frequency band.

The phrase, "Frequency Hopping Spread Spectrum (FHSS)" is used to refer to the technique of transmitting data as a pseudo-random sequence of "frequencies". This has the effect of spreading the band over which the signal is transmitted by a factor corresponding to the number of frequencies per bit.

The term, "handover" is used interchangeably with "handoff." When the bit error rate received from a wayside approaches a programmable threshold, the radio modem initiates a handoff process via the associated carborne router. This process results in the switching of the radio to a channel corresponding to the adjacent wayside location. Once the new link has been established, the carborne router in turn informs the wayside network of the change. Any new communications from the signaling system now automatically and transparently is forwarded to the appropriate wayside radio. Any communication already in transit may arrive at the old wayside radio, which will automatically forward it to the new wayside radio.

The term, "internet protocol (IP)" is used to denote the suite of open standards-based basic protocol underlying the communication on the network in the CBTC system.

The term, "line" is defined in the context of a transit system, within which there may be several lines. These can correspond roughly to the different main train routes.

The term, "macro diversity" refers to the routing of redundant messages (e.g. the train control messages) over routes with as few common pieces of hardware as possible. This helps to ensure that at least one of the messages will reach the intended vehicle controller. The most important piece of the macro diversity is the delivery of the paired messages using physically and temporally disparate routes.

The term, "micro diversity" is used to denote the capability of the radio to select the signal with the best information from more than one received signal over a short time duration related to the rate of change of the signal quality. Such selection must be performed more quickly than the rate of change of signal quality.

The phrase, "Mobile Network Vehicle System (MNVS)" is used to denote the generic name for a vehicle control system based on communication between an on-board vehicle controller and a surface-level controller. The distinction between MNVS and "Communications Based Train Control (CBTC)," lies in the fact that MNVS is wider in scope than CBTC, (CBTC being one example of MNVS), as MNVS applies to the control of vehicles, one example being trains.

The phrase, "Quadrature Phase Shift Keying (QPSK)" is used to denote a type of modulation used to transmit data over modem lines, radio, etc.

The term, "redundancy" is defined as the ability of the system, through the use of redundant components, to survive the failure of one or more components and continue functioning until repairs can be made. This allows a system to built whose reliability is significantly higher than the reliability of any of its components.

The term, "section", is used to define the smallest division of the track. This is a geographic region within a single zone.

The term, "segment" is used to define a single connected portion of the IP network, specifically, the wiring connecting two or more adjacent nodes.

The phrase, "Time Division Multiple Access (TDMA)" is used to denote a communications technique whereby multiple channels of information can share the same physical channel (be it a radio frequency, a colour on a fiber, or a modem line) by interleaving the various channels in time.

The term, "time slot" is used to denote the basic unit of communication on the radio link. A

time slot consists of a transmit phase and a receive phase during which data may be transferred. A frame is made up of a sequence of time slots.

The term, "train controller" is used to in the context that each CBTC equipped train is equipped with a train controller, which handles the communications with the zone controller. The train controller is responsible for determining the train's position, authorizing the train's movements (based on communications with the zone controller) and detecting and reporting the train coupling state.

The phrase, "Universal Datagram Protocol (UDP)" is used to denote a connectionless protocol used to deliver messages on the IP network. UDP does not provide guaranteed delivery or sequencing, but provides a fast mechanism for delivering packets to a known IP address. The train control data is delivered using UDP.

The term, "unit" is used to denote a set of vehicles which are permanently coupled during normal operation. Multiple units can be combined to form a consist.

The term, "vehicle" is used interchangeably with "car" to represent the moving object portion of the system. Thus, it can refer to a train car, bus, trolley car, mine car, amusement ride car, etc.

The term, "vehicle controller" is used to in the context that each CBTC equipped vehicle is equipped with a vehicle controller, which handles the communications with the zone controller. The vehicle controller is responsible for determining the vehicle's position, authorizing the vehicle's movements (based on communications with the zone controller) and detecting and reporting the vehicle coupling state.

The phrase, "Wayside Interface Unit (WIU)" is used to denote the device which connects the wayside (stationary) equipment to the CBTC IP network or the CBTC IP network.

The phrase, "Wayside Radio Frequency (WRF)" unit is used to denote the device at the station which provides the network connection to the trains. The unit consists of an IP router

The term, "zone" is used in the context that each line may be broken down into several zones, each of which is controlled by a separate zone controller.

The term, "zone controller" is used in the context that each zone of track is controlled by a zone controller. CBTC works primarily through communication between the zone controllers for each section of track and the vehicle controllers on each vehicle.

The Highest Level of Organization

At the highest level of organization, the system, termed a Communication System for Mobile Networks (CSMN), comprises four components: 1) one or more fixed networks; 2) one or more mobile networks; 3) wireless inter-connecting means; and 4) open standards-based protocol means throughout the system.

The fixed network

Within the communication system there can be more than one fixed network and mobile network. The fixed network is a collection of communicating devices that are in a substantially fixed location. These devices are inter-connected to form a network, networks, or sub-networks.

The mobile network

A mobile network is a collection of communicating devices that are required to move or be moving from time to time or continuously. These devices are inter-connected to form a mobile network, mobile networks, or mobile sub-networks. This collection of devices communicates with other members of the mobile network or networks and the members of the fixed network or networks. Members of the mobile network may be more or less fixed with respect to other members of the same mobile network.

The wireless inter-connecting means

The wireless inter-connecting means provide a data communication link between the mobile networks and fixed networks as well as a link between two or more mobile networks. Said means does not require a solid physical connection but rather transmits and receives information using a wireless format. In the CBTC embodiment, the wireless inter-connecting means is also referred to as the RF distribution network.

The open standards-based protocol means throughout the system

The open standards-based protocol means throughout the system allows for the possibility of the system to be built using components that adhere to the standards where they exist; where said components do not exist, said means allows for the creation of such components by any interested party skilled in the art. All interface and interoperation points within the communications system are therefore well defined and understood.

1. Overview

The overviews of each level of organization will be outlined as follows. Discussion of communication integrity is located in section 4.3, however, due to its overlap, it is applicable throughout all three levels of the system.

1.1 The Communication System for Mobile Networks (CSMN)

The present invention provides a communication system for mobile networks. The overview of one embodiment of the system at the CSMN level is shown in Figure 1a within the largest box **100**. The central controller **105**, fixed equipment **110** and mobile equipment **170** are not part of the communication system. The overall system **100** includes at least one fixed network **115**, the wireless inter-connect **140** and at least one mobile network **145a** and/or **145b** and/or **145c**, etc.

In the embodiment depicted in Figure 1a, there is one fixed network **115** that includes at least one fixed interface **120** and fixed communication package **135**. An open standards-based protocol **125** connects said fixed interfaces **120** to said fixed communication packages **135**

and with each other. Note that the open standards-based protocol **125** can also connect the depicted fixed network **115** with other fixed networks **115** with additional links **130**.

The Figure 1a embodiment shows three mobile networks, **145a**, **145b** and **145c**, communicating with various objects, using the wireless inter-connect **140** and open standards-based protocol. In one mobile network **145a**, its communication package **155** is communicating with two fixed communication packages **135** using the wireless inter-connect **140**. In another mobile network **145b**, its communication package **155** is communicating with a fixed communication package **135** using wireless inter-connect **140** as well as with third mobile network **145c** using wireless inter-connect **150** between mobile networks. The said third mobile network **145c** is also communicating with another fixed communication package **135**. In this embodiment, the mobile communication packages **155** are connected to mobile interfaces **165**.

1.2 The Mobile NetworkVehicle System (MNVS)

One generalized embodiment of the invention, termed a Mobile NetworkVehicle System (MNVS) comprises: 1) one or more surface-level networks; 2) one or more on-board vehicle networks; 3) radio frequency data links; and 4) open standards-based protocol means throughout the system. The MNVS embodiment of the invention comprises a communication network that provides for positional monitoring and control of mass transit systems. The network comprises a radio-based communications sub-system, intended for use as part of a communications-based vehicle control system. The design is a generic system which can be customized through special interfaces to provide a communication mechanism for different types of mass transport control systems, which allows for the establishment of a communications subsystem for car (train, subway, bus, etc.) control that is based on standard networking protocols. One important result of this design is that it allows for applications and control devices to be chosen from a wider base of suppliers.

The MNVS communications system provides communications between wayside zone controllers and on-board vehicle monitoring and/or control system. The MNVS system requires both RF and other communication connection means. The communications system is responsible for providing reliable message delivery between the zone and vehicle

controllers within specified limits of availability and integrity. This system is a narrower embodiment of the CSMN system, as applied to various types of moving vehicle networks.

1.3 The Communications Based Train Control (CBTC)

One specific embodiment of the MNVS system, termed a Communications Based Train Control (CBTC) system comprises: 1) one or more wayside networks; 2) one or more carborne networks; 3) radio frequency data links; and 4) a standard internet protocol means throughout the system. In one embodiment of the CBTC system, the transceivers employ 2.4 GHz Hybrid Spread Spectrum radio transceivers which employ both Slow Frequency Hopping and Direct Sequence Spreading Techniques, in addition to a half-duplex Time Division Multiple Access scheme which allows one wayside spread spectrum transceiver to communicate with many carborne spread spectrum transceivers at one time.

The CBTC embodiment of the invention comprises a communication network that provides for positional monitoring and control of train and subway train systems. The CBTC communications system provides communications between wayside zone controllers and carborne vehicle controllers. The system requires both RF and other communication connecting means. The communications system is responsible for providing reliable message delivery between the zone and carborne controllers within specified limits of availability and integrity.

Similar to the CSMN system from Figure 1a and the narrower MNVS system, the overview of an embodiment of the CBTC system is provided in Figure 2, wherein there is shown the elements that would typically be included in a CBTC communication system **200**, comprising at least one wayside network **215**, the RF data link **240** and at least one carborne network **245**.

As in the CSMN system, the central controller **205**, wayside equipment **210** and carborne equipment **270** are not part of the communication system **200**. Said central controller **205**, such as Simple Network Management Protocol, can coordinate the distribution of information between networks. Information is dependent upon the architecture of the carborne interface **265**, but would generally include track profiles, details of temporary

restrictions such as track work, and information about operational vehicles. Each wayside equipment **210** and related wayside interface **220** and communication package **235** would optionally feed into a zone controller (not depicted) prior to joining the central controller **205**.

The wayside network **215** includes the elements required to coordinate the safe movement of vehicles operating within a zone. A zone is generally defined as a section of track and its corresponding control elements, such as track switches and other track controls. The zone controller would normally communicate with the vehicles operating within its geographic territory. Vehicles would regularly exchange speed and location information with the zone control subsystem, and this information would regularly exchange speed and location information with the zone control subsystem, and this information would either be distributed to other vehicles within the zone (train based control) or be used to send control information to all vehicles within the zone (zone based control).

The communication system **200** includes elements required to reliably deliver messages between wayside networks **215** and carborne networks **245**. The on-board control subsystem **260** includes the control elements located on-board a vehicle. Each carborne network **245a** and/or **245b** and/or **245c** monitors the speed and location of the vehicle, and is responsible for ensuring the safe movement of said vehicle within prescribed limits, either fully automatically, or in conjunction with a human operator. These limits are determined by knowledge of the vehicle parameters (e.g. braking characteristics), track parameters (e.g. speed restrictions, switch positions, work areas, station locations), and the location and speed of other vehicles.

The carborne equipment **270** includes the elements required by the carborne networks **245** to determine vehicle location and speed. Generally this would include some form of axle tachometer and a mechanism to "zero" the absolute location, such as a transponder device located along the rails or a differential Global Positioning Satellite (dGPS) receiving system. Absolute location is a key element of any vehicle control system, and is generally computed as the elapsed distance from a known (i.e. zero) fixed location.

The CBTC system elements embodied in Figure 2 primarily comprise: one or more wayside interface units **220**; one or more wayside communications packages **235**; one or more

carborne communications packages **255** having carborne interfaces **265** and a RF data link or distribution network **240**. As before, the wayside network which may, for example, correspond to one line, can be connected to other wayside networks corresponding to other lines with the IP standard links **230**. The wayside interface unit **220** consists of a standard computer means, with interfaces to the zone controller (not depicted). Each wayside communications package **235** is located at easily accessible locations, and is used to provide the link between the wayside networks **215** and RF data link **240**. It will consist of one or more router/controllers, redundant RF modems, and a power supply. The carborne communication package **255** is located on the vehicle, and consists of an on-board router/controller, and one or two radio modems. The RF data link **240** utilizes a "cellular" architecture, where each wayside communications package **235** provides coverage over a dynamic geographic area, or cell. Adjacent cell coverage overlaps, to ensure continuous coverage. The RF data link **240** is site specific and requires detailed knowledge of the environmental conditions that could effect signal propagation. Considerable on-site testing is required to determine the exact location and configuration of the fixed RF data link **240**. In general, one method of distributing the RF signals is directional point antennas located at stations or other easily accessible wayside locations. In some instances, it may be necessary to implement a hybrid solution, utilizing a combination of point and distributed (i.e. slotted waveguide or leaky "feeder" coax) antennas to achieve the required level of RF coverage and/or protection from interference. The carborne antennas may be either patch antennas mounted on the front of the train, or ruggedized directional antennas mounted on top of the vehicles.

In this embodiment, the wayside network **215** is a standard wide-area network (WAN), consisting of standard routers and modems using standard transmitting means to inter-connect the zone control subsystems and the wayside communications packages **235**. Since standard means are employed, any appropriate existing or planned infrastructure could be used.

2. The Fixed Network

2.1 The Communication System for Mobile Networks (CSMN)

Within the CSMN, there can be more than one fixed network. The fixed network is a collection of communicating devices that are in a substantially fixed location. These devices are inter-connected to form a network, networks, or sub-networks.

2.2 The Mobile NetworkVehicle System (MNVS)

The fixed network in the MNVS is restricted to surface-level networks.

2.3 The Communications Based Train Control (CBTC)

The wayside network, as its name implies, interconnects a signaling company's train control systems and RF radios located along the side of the track. Interface points allow other supervisory or management equipment to connect to the wayside network.

The network is composed of two parallel networks. IP address assignment and routing is set, such that the preferred path for IP packets with a destination IP address that lies in a specific IP sub-network, is different from the preferred path of IP addresses that lies in another IP sub-network . Each of the two parallel networks is primarily responsible for carrying IP packets of a certain IP address flavour.

The two networks are interconnected at each node. This interconnection ensures that if one network, or part of a network, fails then traffic that is supposed to travel over the failed network path will cross over to the other network and travel to the nearest point where it can travel over its 'own' network.

In one embodiment, one possible organization is that a Class A network be used, with subnet number 1 (flavour "A") ranging in values 10.0.0.0 to 10.0.127.0 and subnet number 2 (flavour "B") ranging in values 10.0.128.0 to 10.0.255.0. This arrangement in IP addresses provides a 1 bit difference between the 2 subnets. The 2-subnet arrangement is referred to as "flavouring". In an alternative embodiment, rather than using the Class A IP addressing for the WRF network, Class A is used for the vehicles. The 2-subnet organization can still be

used. Figure 4 illustrates one example of how a portion of the WRF network may look using the Class A IP addresses.

The wayside network is a fully redundant, primarily linear, network, which connects wayside stations to their 'upstream' and 'downstream' neighbors. The minimum configuration for a wayside network node is a redundant set of RF capable IP routers. Connections between wayside network nodes are made using point-to-point, redundant fiber optic cables operating at 10 Mbps.

Each wayside station, through the wayside RF capable IP routers, provides a connection to the RF distribution network, which links the wayside and the carborne networks.

A key component of the present invention is the radio, which has been designed to operate efficiently and reliably in harsh environments such as a subway system where signal channeling, multi-path distortion and intermittent blockage by train cars occurs on a continuous basis.

The system is a clear improvement over traditional fixed-block systems in that it allows for increased system capacity and very high availability. Moreover, the present invention reduces the possibility of human error by automating many manual operations

With reference to the embodiment depicted in Figure 3, the wayside communications package **335** consists of a router **330** and one or two radio modem(s) **340**. Each router **330** is connected to other routers via an IP router **320**, and optionally to adjacent wayside routers **330**, using standard transmissions means, such as 56 Kbps-2048 Mbps connections or Ethernet connections, thereby forming the fixed WAN. The router **330** also has links to each wayside radio modem **340** for data, such as 64-256 Kbps and for control, such as 9600 bps.

The wayside radio modems **340** are a critical component in the RF link. The transceiver architecture has been designed to be adaptable and capable of operation in a variety of hostile environments. In designing the radio, factors such as the physical environment, vehicle control data transfer requirements, channel requirements, and expected the RF environment must be considered. The radio modems operate in half duplex mode, using time division

duplex to provide bi-directional communications between the wayside equipment and on-board equipment. Communications would operate with wayside radios alternating between transmit and receive, and on-board radios transmitting only in a wayside receive "window."

Each carborne communication package **345** comprises a router **360**, which is connected to one or more carborne radios **350**, and is configurable for whatever connection is appropriate for communication with carborne train control equipment.

Figure 3 describes one embodiment wherein message routing is conducted by assigning to each vehicle a unique IP network number. Each on-board router **360** is assigned an IP address belonging to the network on the train on which it is located. All IP routers, such as **310, 320, 330** and **360**, maintain IP routing information for all networks on vehicles and all fixed networks.

Each wayside edge router **330** repeatedly transmits an outbound data stream over the active radio modem **340**, in a time-division duplex mode. The size of the outbound data packets is configurable to optimize throughput, and contains the identity of the cell that the wayside edge router **330** is controlling. When the wayside edge router **330** receives a message to send to a vehicle, said message is sent by said wayside edge router **330** into the outbound data stream.

Each carborne radio modem **350** continuously monitors the outbound data stream from the wayside edge router **330** to which it is "connected," and forwards any messages addressed to it on the carborne vehicle control equipment **365**. Messages received from the carborne vehicle control equipment **365** are transmitted by the on-board router **360** over the active radio. The on-board router **360** routes incoming messages via the carborne network **345** to the intended destination.

The speed of delivery of messages in a vehicle control application such as a train or subway system is a key issue, as critical messages can lose their significance if they are delayed. There is therefore a need to provide multiple levels of priority, to ensure that time sensitive data can pre-empt lower priority transmissions and thereby not be unduly delayed in the delivery process. Typically, high priority messages can be delivered with a latency of 50 to

250 ms although during handoff, this could increase to as much as 500 ms in a worst case scenario.

Considering that an intranet used for the communication system is optimized in its structure, it should be configured so that the number of hops from train to central (or vice versa) are kept to a minimum. In a well designed intranet, it is not uncommon to see one way transmissions of messages in less than 150 ms with 8 routers/hops in the path. The vehicle control system itself has to incorporate a mechanism to deal with "stale" messages.

To ensure guaranteed, in-order, delivery of all critical control messages from the signaling system to a vehicle, the network interface unit **310** needs to use a higher level protocol to transmit said messages over the communication system. This architecture seamlessly scales to larger, more complex networks.

3. The Mobile Network

3.1 The Communication System for Mobile Networks (CSMN)

In the CSMN, a mobile network is a collection of communicating devices that are required to move or be moving from time to time or continuously. These devices are inter-connected to form a mobile network, mobile networks, or mobile sub-networks. This collection of devices communicates with other members of the mobile network or networks and the members of the fixed network or networks. Members of the mobile network may be more or less fixed with respect to other members of the same mobile network.

3.2 The Mobile NetworkVehicle System (MNVS)

The mobile network in the MNVS is restricted to vehicle networks.

3.3 The Communications Based Train Control (CBTC)

The carborne network, like the wayside network, is based on the IP routing paradigm. The minimum configuration for a carborne network is a redundant set of RF capable IP routers

located at each end of a multi-car train unit. Carborne devices capable of attachment directly to an IP-based LAN can be connected to the redundant network provided by the carborne radio units. Since existing on-board Train Controllers do not have IP capable local area network interfaces, a carborne interface unit (CIU) provides a protocol conversion gateway service for the on-board Train Controllers. The CIU also provides gateway services for networks such as LonWorks™.

In an example of one embodiment, Figure 5 illustrates how a portion of the Carborne network may look using the Class A IP addresses. This exemplary network layout illustrates the connections and organization of the CRFs and CIUs. In a 4-vehicle set with both CIUs in the same car, the CIUs are connected to each LAN as shown by the dotted and dashed lines. The CIUs are in the 2nd and 3rd vehicle for certain types of vehicles. In this example, the carborne configuration is only allowed to run a maximum of two twisted pair cables between cars. In general this means that each CIU is directly connected to only one network and therefore it has only one IP address. For vehicles where the CIUs are located in the same car, said CIUs are connected to both networks.

In certain embodiments, more than one vehicle is linked together such as multi-train or subway-train units. In these cases, each multi-vehicle unit has two operational radio transceivers, one at each end of the each unit. Each radio transceiver attempts to become a member of a RF communication cell by a process called acquisition. The management of mobile radios within wayside cells is completely controlled within the communication system. No intervention from the car control system is required.

As seen in Figure 3, there are two basic communication packages: a wayside package and a carborne (or vehicle-based) package. Each package minimally comprises a RF transceiver, a router, and an antenna.

The Router

An embodiment of the present invention further involves RF routers (located in the wayside and carborne communication packages) which are interfaced with similar Hybrid Spread Spectrum radio transceivers along the wayside and on the vehicles. These RF capable routers

employ both Slow Frequency Hopping and Direct Sequence Spread Spectrum techniques. In one embodiment the Hybrid Spread Spectrum radio transceivers operate at 2.4GHz. The wayside-to-train RF data link employs a half-duplex Time Division Multiple Access scheme which allows one wayside Spread Spectrum transceiver to communicate with many carborne Spread Spectrum transceivers simultaneously. Adjacent wayside communication cells use different Slow Frequency Hopping patterns which are not synchronized, wherein a frequency hop is in the order of the length of a duplex Time Division Multiple Access frame. There are a limited number of Slow Frequency Hopping carriers but a frequency hopping sequence can be reused based on distance separation. Frequency hopping sequences for adjacent cells are designed such that two consecutive frames will not collide.

In one embodiment, the radio means employs spread spectrum modulation techniques, wherein a primary bandwith spreading technique such as the Direct Sequence Spread Spectrum technique is used. It is capable of employing a Gold Pseudo Noise code, which is a minimum of nine orthogonal codes available in the 63 chips/symbol scheme. The base band data is modulated and demodulated using Differential Binary Phase Shift Keying or Differential Quadrature Phase Shift Keying. The radio shall superimpose a Slow Frequency Hopping/Direct Sequence Spread Spectrum scheme as the inter-cell access method.

The Router is a multi-port device that performs the standard routing of IP datagrams. The router must support LAN (Ethernet) type ports and other high speed serial ports. The router must also support automatic updating of routing information based on network topology changes using a standard routing protocol, such as Routing Information Protocol (RIP) and Open Shortest Path First (OSPF).

Within a CBTC system, there is a possibility of providing different classes of service for different types of data. This implies that the routers can support IP prioritization, that is, the router first processes IP datagrams with the highest priority class of service.

In a CBTC environment, most systems broadcast messages in order to initiate communications with mobile trains that may be entering a given control area. Since broadcasting these messages throughout the complete data communications network may not always be desirable, there may be a need to implement an IP multicast function. With such a

function, individual wayside RF routers can participate within different multicast groups based on configuration or dynamic network conditions. The need for this feature depends, of course, on the specific requirements for each application of this system. There is an indication that the required broadcast simulation can be implemented with the use of only unicast datagrams. Therefore, the timing of the availability of this feature depends on the needs identified by the individual application.

The routers used for the network interface units (WIU, CIU) preferably require high speed serial ports with customer specific interfaces. In general these ports typically support asynchronous, synchronous, low speed to 1 Mbps, framed and unframed type messages. The network interface units preferably provide interface to networks such as LonWorks™.

During the acquisition phase, the radio module determines the possibility of establishing a channel with another radio. The information about the channel is passed to the router, which is then responsible for deciding if the channel is required and the actual channel assignment process. Since the radio uses a TDMA scheme to allow multiple radios to communicate at the same time, the router must perform some of the data alignment required by this scheme. The router must be aware of the number of time slots and which virtual channel uses which time slot (or slots). The router must then orient transmit data into frames that can be sent by the radio module. Frames received from the radio must be dissected so that data can be assigned to its proper virtual channel

By way of example, the following Logical Link Control functions are accomplished: 1) allocation of TDMA time slots to carborne RF routers; 2) generation of data field of TDMA time slot; 3) presentation of data field to RF section in order-of-time-slot; 4) specify the 'current' carrier, that is, the carrier on which to transmit and receive; 5) describe system carriers to RF section (specifies each carriers slow frequency hopping pattern and PN code); 6) release of time slot / carrier; 6) specification of 'current' carrier (specification of new carrier); 7) specification of 'current' receive time slot(s) each TDMA frame; 8) specification of transmit time slot each TDMA frame; and 9) interpretation of TDMA control information in 'control / broadcast' time slot.

In one embodiment, the carrier to be used by the radio module to establish a channel with

another radio is defined by the SFHS and pseudo noise code (PN) used to spread the data. The router informs the radio which SFHS, PN code pair to use for communications.

The wayside RF router implements a TDMA scheme wherein the router informs the radio module which time slot (or slots) are to be used. For example, the first time slot can be reserved for broadcast, control, error recovery, acquisition and a low speed collision detection based channel.

The CBTC router implements a 'bandwidth-on-demand' capability wherein more than one pair of time slots can be allocated to the same carborne RF router for data transmission between a wayside and carborne transceiver. The allocation of a frame's receive and transmit time slots is communicated in the first time slot of each frame.

By configuration, the router can implement a data encryption capability. Additional data protection can be provided on the RF data link by encrypting the data with a method compliant with Data Encryption Standard (DES). For example, the encryption can use a secret 56 bit key which is stored within the RF transceivers and is not retrievable. This encryption key can be changed by a secure method. A method that coordinates the updating of secret key usage within the overall system could be implemented such that disruption to the system (through loss of secure communications) is minimized.

The use of a secret key system significantly reduces the burden associated with key management. If stronger encryption is required, it is possible to implement a public key system via, for example, a hardware PCMCIA-compatible encryption processor. In such a case however, key exchange would be required with every RF link setup as trains move from cell to cell.

In one embodiment entailing SFHS, the carborne radio has the capability of transmitting and receiving on at least seven eight-MHz slow hopping frequency bands in the 2400 to 2483.5 MHz ISM band. The carborne radio can define at least six orthogonal frequency sequences that have one-frequency "hit" between sequences. Hereinafter a frequency hopping pattern coupled with a direct sequence PN code is referred to as a 'carrier'. In such an embodiment, the Slow Frequency Hopping rate is one hop per frame ($T_x + R_x$ for one time slot). Since the

hopping rate is synchronous with the frame rate, there is no need for separate frequency hopping tracking and frame tracking mechanisms.

Frequency hopping sequences for adjacent cells are designed such that two consecutive frames will not collide. To deal with frequency "hits," the transceiver employs different PN codes for different hopping sequences, forward error correction and supports antenna micro diversity. Typically, adjacent wayside RF communication cells use different frequency hopping patterns and different direct sequences (i.e. different carriers).

In one embodiment, the carborne radio implements a TDMA scheme in which each frequency hopping carrier is subdivided in the time domain into '2k' time slots, the use of which provides 'k' duplex data channels where $1 < k < 10$. The frame multiplexes data and control information. During the first half of the frame (W-T in Figure 6), the wayside transmits and during the second half of the frame (T-W in Figure 6), the carborne transceivers transmit.

4. Wireless Inter-Connecting Means

4.1 The Communication System for Mobile Networks (CSMN)

In the CSMN, the wireless inter-connecting means provide a data communication link between the mobile networks and fixed networks as well as a link between two or more mobile networks. Said means does not require a solid physical connection but rather transmits and receives information using a wireless format.

4.2 The Mobile NetworkVehicle System (MNVS)

The Transceiver

The radio modem is a high performance spread spectrum radio transceiver that makes extensive use of digital signal processing. As shown in Figure 7, one example of the radio transceiver may consist of six functional blocks: 1) a RF Up-Down Converter; 2) an Analog

IF; 3) a Digital Wide-Band IF Processor; 4) a Spread Spectrum Processor; 5) a Base-Band Burst Processor; and 6) a Control and Interface Processor.

Figure 8 presents an embodiment that is exemplary of the receive (R_x) section of the RF Up-Down Converter/Analog IF which amplifies the signal received from the antenna, filters unwanted signals and translates the information to a lower frequency in order to be conveniently digitized. The transmit section (T_x) modulates the carrier with the base-band information and then up-converts and tunes it to the final desired RF frequency. The RF Up-Down Converter is frequency agile and capable of operating in a slow frequency hopping mode. After down-conversion to IF, the received signal is processed in the digital domain.

Figure 9 presents an embodiment that is exemplary of the Digital Wide-Band IF Processor which performs the down-conversion of the received signal to the base-band. It provides high tuning resolution, excellent filter selectivity and programmability that allows adaptive filtering.

In one embodiment, the Spread Spectrum Processor implements a fast acquisition, direct sequence spread spectrum full or half-duplex system using differentially-encoded BPSK or QPSK. It integrates the capability of a digital down-converter, PN matched filter and DPSK demodulator into a single receiver. Viewed as a receiver, its input would be the analog-to-digital converted IF and the baseband output of the Digital Wide-Band IF Processor. The transmit section of the Spread Spectrum Processor outputs the spread baseband signal to the vector modulator in the RF Up-Down Converter.

In one embodiment, the Baseband Burst Processor formats the over-the-air data burst. In transmit mode, after passing the data message through the forward error correction (Reed-Solomon) encoder, the burst processor appends the over-the-air header and delivers the appended data message to the transmit section of the Spread Spectrum Processor. In receive mode, the Baseband Burst Processor takes the demodulated data burst from the Spread Spectrum Processor and processes the header. Next, the data burst is decoded by the Reed-Solomon circuit and sent to the Control and Interface Processor.

The Control and Interface Processor role is to configure the programmable signal processing

circuits and to interface to the CBTC Router. Physically, these six functional blocks form two sections, on two different PCBs, as follows: 1) the RF Section which consists of the RF Up-Down Converter and the Analog IF use a single PCB (the "RF Board") with the appropriate shielding for the high frequency circuitry; and 2) the Digital Wide-Band IF, the Spread Spectrum Processor, the Baseband Burst Processor and the Control and Interface Processor circuitry (the "Digital Section") resides on another PCB (the "Digital Board"). It is possible for the radio to use a different "RF board" to allow use together with the same "Digital Board" the operation in a different frequency band.

In one embodiment, the RF Section implements slow Frequency Hopping (FH). While transmitting or receiving data, a new frequency shall be chosen pseudo-randomly from a field of 17 frequencies (f1 to f17). Sixteen maximally uncorrelated length frequency sequences can be provided, as shown in the example at Figure 10.

There are three operational modes: standby, receive and transmit. In standby mode, the RF Section is not capable of transmitting a signal. In receive mode the RF Section is configured to receive a radio signal and to provide a second intermediate frequency analog output. In transmit mode, the RF Section is configured to transmit the desired baseband filtered I and Q signals.

In one embodiment, it is possible to start receiving modulated IF signal within a maximum of 50 microseconds following the command (at the SPI port) to switch from transmit to receive mode. It is also possible to start reliably transmitting I and Q signals within a maximum of 50 microseconds following the command (at the SPI port) to switch from receive to transmit mode.

In yet one more embodiment, the radio shall generate its own over-the-air-preamble and header information. In transmit mode the Baseband Burst Processor formats the over-the-air time slot. In receive mode the Baseband Burst Processor processes the Start of Frame Detector (RF_SFD) and control (RF_CTRL) fields.

In another embodiment, the "acquisition preamble" always uses the same 63 chip code (**PN_0**). The remainder of the time slot uses another code (**PN_j**).

The TDMA frame shall consist of a programmable number of transmit (TS) and receive (**RS**) pairs of time slots. The guard time between TS and RS shall be less than 125 microseconds. When frequency hopping is used, the frequency shall change after every pair of **TS+RS**. The guard time when a frequency change is required shall be less than 250 microseconds.

4.3 Communications Based Train Control (CBTC)

Communications Integrity

Information passed between the zone and vehicle controllers is considered "vital," that is, the messages contain information essential to the safe operation of the vehicle system. Lack of reliable communication can severely impact the performance of the vehicle control system. Therefore, a very high level of system availability is required.

One function of a CBTC data communications system is to reliably exchange messages (information) between fixed, wayside vehicle control processors/controllers and mobile, carborne vehicle control processors/controllers. To be useful, this exchange of information must be accomplished in a reasonable amount of time. In one embodiment, CBTC systems are designed such that if a vehicle does not communicate with a wayside controlling entity within a specific period of time, such as two to five seconds, the vehicle automatically stops.

The design is based upon comprehensive knowledge of the actions of the data communications system to be controlled. A specific CBTC data communications availability requirements is met with tools such as redundancy, quality, failover, hardening, fault tolerance, testing and adequate supply of easily replaced modules.

One way to increase the availability of a CBTC data communications system is through redundancy and failover. The CBTC network is an IP network with special characteristics designed to improve the overall reliability for the train control messages. Since it is an IP network, any reasonable number of link failures is handled automatically by the IP routing capabilities.

To ensure that the risk of losing messages in the event of failure is minimized, all train control messages are transmitted redundantly and routed to take advantage of the macro diversity given by the radios located at more than one point along the train. Since the IP network is designed to route around failures, IP handles failure recovery. By manipulating the metrics for various routes, based on the IP destinations, the chance that redundant packets will travel over different routes is maximized.

In one embodiment, the entire network is designed with a high degree of redundancy. Every unit, including the wiring, has a redundant partner. The entire system will keep working, with minimal interruption, in the event of failure of any single component. The objective of this redundancy design is to provide a high degree of fault tolerance so that the system will keep operating reasonably well, even in the event of multiple (related or unrelated) failures.

The WIUs, WRFs, CRFs and CIUs are arranged in redundant pairs, with either unit able to take on the full load in case of a failure of the other. All wiring is arranged in redundant pairs, with either connection able to carry the messages in the event of failure of the other. An important aspect of the redundancy is that all the units will be continuously exercised and the failover will be as fast as possible. Ideally, failover could occur without losing any messages. Realistically however, one objective is to failover with only one missed message.

Another important consideration is the speed with which the redundancy must work. Since the network is delivering train control messages, any failover will imply loss of these messages. Even though the messages are redundant, to protect against such loss, any single failure must be detected and corrected in a short period of time, for example within 3 seconds. This level ensures that a single failure will not cause the onboard controller to lose confidence in the link and initiate train braking.

The routers, which are providing radio functionality, and the WIU's and CIU's also use backup redundancy. During normal operation, only one unit provides active support for the train control network, while its partner is ready to take over if necessary. Much of the backup redundancy will be initiated by the redundant unit detecting that it is not working as well as it should. If a redundant partner detects a possible failure while monitoring its active partner, it

may choose to initiate a failover. In this case, the partner has determined that there is a problem assumes control by initiating an involuntary failover.

In one embodiment, a simplified redundancy scheme can be used. This scheme protects against the complete failure of any component, such as the wire, router or radio, but not against all the other failure modes. The implementation still needs to include the active polling of the partner, the failover mechanism, and reporting to the central controller, if any.

When a unit starts up, it first verifies basic operation, then operation as a router, then as a CBTC Backup, and finally, as a CBTC Active unit. At any stage, it may decide not to proceed. Indeed, at the last stage, it does not proceed to become the Active unit unless there is no other Active unit. This staging mechanism allows the implementation of a graceful startup and degradation of the system.

When either partner determines that a failover is required, the information is passed to the Backup unit, and the Backup decides whether or not to take over. To ensure that both units are basically operational, both units actively poll their partners at a reasonably high frequency, such as a few times per second. Should either unit fail to respond, the other will start downgrading the known capabilities of the partner.

Each CBTC unit conducts a fault analysis. This task runs periodically to determine the capabilities of the unit and its redundant partner. As well, each redundant partner includes a fault analysis task, which runs periodically to determine the health of the unit, verify its connectivity to the outside world, and determine whether it should initiate a failover to or from the partner unit. The task probes the unit to determine its capabilities and handles the polling messages between the unit and its redundant partner. To ensure that all the equipment is periodically tested, the units, which are paired based on backup redundancy, periodically pass control from the Active to the Backup unit. This follows the same basic mechanism as the normal failover, except that it may be prevented if the Backup unit is not "healthy" enough.

The actual handover of control is controlled by the Backup unit. In cases where the Active unit wishes to surrender control, it will do so by asking the Backup to take control, rather than by passing control to the Backup. This means that control will only be passed when there is a sufficiently healthy Backup ready to assume control. The one exception is when the Active unit has failed badly enough that it cannot continue operation. In this case, the Active unit will simply cease to operate (at least as a CBTC unit), and the Backup will seize control when it detects the lack of an Active unit.

The Active Partner and the Backup Partner can periodically poll each other. In this embodiment, control is assumed by the partner having greater capabilities. One of the tasks of fault analysis is to ensure that there is always some valid routing information in the standard routing protocol table, or that at least one link is plugged in. If the fault analysis task ever detects that there are no valid connections to the outside world, it enters a voluntary failure mode.

For the WRF and CRF units, the Backup partner keeps the radio in a monitoring mode. In this mode, it is able to detect the transmissions of its partner. In all cases, the Active WRF should be transmitting and receiving. If either partner determines that one direction is not working, this may form the basis of a failover negotiation.

Antenna wire failure is a special case. If one of the antenna wires breaks, and there are no trains in the cell, then the Backup will fail to hear anything from the Active. This situation needs to be detected, and the switching to continue, so that when a train enters the cell, it will be picked up quickly by one of the partners, even if the wrong one happens to be active when the train actually enters. The constant switching thus occurs during a short time period, such as once per frequency hopping cycle. If either partner hears anything, the switching cycle increases.

The hardest case for the redundancy to detect and correct is the failures which leave both partners fully functional, but unable to talk to each other. In this case, it is difficult to determine which one should become the Active unit. The present invention overcomes this problem by forcing a unit to fail when it has no routes other than those across the radio. In

doing so, an operational unit which loses all of its links becomes non-operational, thus breaking the deadlock.

One skilled in the art will appreciate the requirement for redundancy. The WRF's and CRF's are arranged in redundant pairs so that failure of the radio will have a minimal impact. The redundant partner in a radio pair continuously listens to the transmissions of the active radio and can thus determine whether a failover is required. If the active radio fails to transmit a correct packet, the redundant partner may initiate a failover.

The mobile radio expects to constantly hear frames from the wayside. If the mobile radio does not hear anything in a cycle, it will ask its redundant partner if there is a problem, by offering via the mobile network a voluntary failover, with a cause of "no radio to wayside". If the redundant partner can still hear the wayside radio, then it will accept the failover and will take over as the active radio device. However, if the redundant partner cannot hear the wayside, then it will reject the failover, and the original device will remain active. If a complete set of frequency hops occurs without either radio being able to hear the wayside device, then the wayside will be assumed to have failed, and the carborne devices will initiate a failover to the redundant route. This kind of failover could be caused by various problems, such as failure of the wayside, loss of radio signal, or jamming.

Once a mobile has signed on to a wayside cell, the wayside is responsible for ensuring that the mobile remains active. The wayside retains a polling list based on each frequency hop for each mobile. It is desirable for the wayside to be able to differentiate between the loss of a mobile and the loss of synchronization in the frequency hopping sequence. When the radio fails, it no longer asks for more slots. As such, the radio naturally takes itself out of operation. The router can protect against radio failure by simply maintaining a timer from the last time the radio asked for data.

One objective of the system is that a central controller, such as Simple Network Management Protocol (SNMP) known to those skilled in the art, should be informed whenever faults occur which affect operation. In particular, SNMP should be notified whenever a fault occurs which indicates that a repair is required.

Each CBTC unit has different levels of service which it may provide. An Active CBTC unit actively participates in the CBTC operations, and maintains a dialog with its redundant partner. A Backup CBTC unit does not participate in CBTC operations, but uses its CBTC interface (radio or ZC/TC interface) to assist in determining whether the Active unit is operational. A Failed CBTC unit is a unit that has experienced a failure which causes it to be unable to operate reliably as a CBTC unit. Once the Failed CBTC unit is repaired however, it may be upgraded to a higher status. In all cases, any unit which is either in a failed mode, or which is aware of a failed partner will attempt to communicate that failure to the SNMP manager.

When an Active unit determines that it is not fully functional, it sends a "Voluntary Failover" message to its partner. If the partner has better capabilities, it will accept the failover and will immediately initiate control seizure. Since the control seizure is expected, the Active unit immediately responds with an acknowledgment and ceases CBTC operation. Since the seizure message is protected, even a message failure at this level will only cause a temporary glitch in the system.

When a Backup unit determines that the Active unit is unable to continue operation, it will send a "taking control" message. Once acknowledged, the Backup unit will check what it can for the Active unit getting out of the way. For example, in the case of a radio unit (WRF or CRF), the Backup unit will check that its partner's radio does not transmit during the next required time (next slot for WRF or next response for CRF). Once it is satisfied that the partner is out of the way, the Backup unit will activate its radio and become the Active unit.

When a unit determines that it is unable to continue operation, it will downgradc from a CBTC unit to a simple router. As a router it may continue to operate to the best ability given the failures and the local environment. Once it ceases to be a CBTC unit, it will not transmit anything over the radio.

Since all the backup routers and wiring are already active, there is no need to provide scheduled failover between the components. However, there remains a need to provide continuous checking for all links and nodes, particularly the links between the redundant partners that are otherwise underutilized. The radios operate in an Active/Backup

configuration, with the Backup radio operating entirely in receive mode. Since this does not provide any assurance that the backup radio is able to transmit, periodic failover from the active radio to the backup radio can be performed.

When a WRF or CRF decides to failover voluntarily, it will send a "Last Transmission" indicator in its control slot (slot 0). This has no particular significance to the other end of the radio link, but immediately tells the redundant partner to take over control of the radio link and to update the routing information accordingly. If the failover can be accomplished in under one message cycle, then this form of failover provides the ability to test the redundant partners on an ongoing basis without introducing any additional chance of message loss.

After running for an extended period of time, such as one hour with a capable partner, a WRF or a CRF should relinquish control to the partner in order to exercise the partner's radio (specifically in transmit mode). There is a minimum time, such as 10 minutes, before which no voluntary failover will be scheduled. There is also a maximum time, such as 24 hours, after which the failover will be scheduled, even if the load is not low enough. By choosing the minimum and maximum times appropriately, this voluntary failover will have very little effect on the normal operation of the system.

In the case of transit applications, typically there is multiple sets of on-board equipment within a single train. For example, in most subway applications, trains are made up of "married pairs", where a married pair consists of permanently coupled A and B units. For RF propagation reasons, each end of the married pair may require a separate carborne radio/controller with its associated antenna. It would be desirable to utilize an on-board LAN.

Furthermore, a train may consist of two or more married pairs, which further complicates the distribution of information between multiple pieces of equipment on-board a train. It would be prudent to consider the ability of the communications system to utilize the radio network to not only pass information to and from trains and the wayside locations, but also to distribute said information between different pieces of equipment aboard the same train. The CBTC system must deal with the possibility of communication subsystem failures, which could affect a single train, or all the trains within a sector.

In an alternative embodiment of the present invention, a security system can be installed, for example, the radio transceiver can implement a data encryption capacity. Additional data protection can be provided on the RF data link by encrypting said data with a method compliant with Data Encryption Standard. Such an encryption could use a secret key, such as 56 bits, which is stored within the RF transceivers and is not retrievable.

In one embodiment, such as a multi-line subway system, it is recognized that contracts may be awarded to more than one train service provider. For that reason, the system's interface is provided between the WIU and the Zone Controller and between the CIU and the Train Controller. The details of the interfaces will be specific to a particular signaling system.

For example, these interfaces can be X.21, V.35 or V.24 compliant physical connections with the WIU or CIU providing a DCE interface. Note that the WIU and CIU hardware provides standard DTE physical interfaces. This allows for the possibility of a variety modem/line driver equipment between the interface units and controller.

The CBTC offers improved capacity over existing systems because it is able to locate vehicles with greater precision. By knowing more precisely where vehicles are located, the present invention can operate vehicles closer together.

CBTC systems can use microcomputers making it practical for two or more to be configured in parallel so that when one fails the system is able to seamlessly switch over to a working unit. This "fail-operational" aspect of CBTC is attractive because it reduces the frequency of service disrupting failures and allows more flexibility in managing maintenance crews.

RF Distribution Network

Each wayside network node manages one RF communication cell. The RF distribution network provides redundant RF data links between the wayside network and each carborne network. In one embodiment, each multi-car train unit has two RF data links to the wayside network, one from each end of the train unit. As the train moves, each radio transceiver will independently attempt to find a better wayside cell. When an on-board RF capable router

switches to a new cell, it immediately transmits a routing information packet to update the wayside network routes on the most direct path to reach the IP networks in the carborne network by a process known in the art as a handover. Handover is independent from the train control system and has no impact on train control communications.

5. Open Standards Format

5.1 Communication System for Mobile Networks (CSMN)

The use of open standards-based protocols within the communication system provides an opportunity for interworking with other types of communication systems. Since the protocols used are well specified and understood by the industry, even if the communication system has to interwork with other non open proprietary systems there will usually be people skilled in the issues that arise from such a requirement.

5.2 Mobile NetworkVehicle System (MNVS)

The architecture of communication systems for vehicle control are not normally viewed as open networks in the modern sense of the term despite the fact that they may claim to conform to the OSI Reference model. They are normally based on proprietary hardware and protocols that are not inter-operable with equipment from various vendors. The aim of the communications architecture of the present invention is to apply recent enhancements in open network features with advances in wireless communications to create a truly open network infrastructure that could be overlaid on a vehicle control system.

5.3 Communications Based Train Control (CBTC)

TCP/IP based networks are the most open network topology available. Products from thousands of companies can use internet protocol (IP)-based networks to intercommunicate at all layers of the OSI model. IP-based networks are normally used to interconnect fixed location computers and workstations. In a vehicle control system however, all nodes located on vehicles cannot be connected using a fixed link. As a vehicle moves along a track, the wayside radio station, to which it has a wireless connection, changes. Thus the path from a

central control system to a node located on a train changes continuously. Fortunately IP contains mechanisms to handle changing network topologies, for example RIP and OSPF. These routing protocols allow any node to maintain communication with any other node on the network. They are also dynamic, so that if the network changes (e.g. due to failure of a link), an alternate path, if available, will be used.

In the CBTC embodiment, the main interoperability points are: 1) between fixed networks (the fixed network to network interface), 2) between the mobile networks and the fixed network (the over the air interface) and 3) between mobile networks (the mobile network to network interface). An example of this interworking could be: a subway system that contains at least two lines with equipment from different suppliers. In this case one fixed network may be supplied by supplier A using the invented technology and the second fixed network from supplier B. Since the lines may have different control schemes, the communications that take place on the two fixed networks may be different. Finally, all of the subway cars may contain mobile networks and these cars may be supplied by different vendors. As in the broader systems, communications that take place within each type of mobile network and possibly between a mobile network and each fixed network may be different but the requirement to communicate between all of these networks remains. Since the cars must be able to move from line to line as well as couple to other cars, these mobile networks must not only interwork with the two fixed networks but also with each other.

The use of open standards-based protocols enables a reasonable implementation of these interoperable interfaces that allow for the use of various networking technologies that are optimized for each application.

Other examples could be even more dependent on interworking as in the example of automobiles operating on public highways. The vehicles are from many manufacturers and contain many different types and levels of technology. The vehicles move across many different infrastructure jurisdictions with not only differing technologies but also different policies. While setting a standard is clearly required, thc usc of open standards allows for rapid development without the normal need for additional coordination.

From the foregoing, it will be appreciated by one skilled in the art that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

WE CLAIM

1. A communication system for mobile networks comprising:
   i) a fixed network;
   ii) a mobile network;
   iii) wireless inter-connecting means interconnecting the fixed network with the mobile network; and
   iv) open standards-based protocol means throughout the system.
2. The communication system as in Claim 1, wherein said mobile network is a mobile vehicle network.
3. The communication system as in Claim 2, wherein said fixed network is a surface-level network.
4. The communication system as in Claim 3, wherein said mobile vehicle network is an on-board vehicle network.
5. The communication system as in Claim 4, wherein said wireless inter-connecting means is radio frequency means connecting the surface-level network with the on-board vehicle network.
6. The communication system as in Claim 5, wherein said surface-level network is a wayside network.
7. The communication system as in Claim 6, wherein said on-board vehicle network is a carborne network.
8. The communication system as in Claim 7, wherein said radio frequency means is radio frequency means connecting the wayside network with the carborne network.
9. The communication system as in Claim 8, wherein said open standards-based protocol means throughout the system is a standard internet protocol means.
10. A communication system as in Claim 1, comprising:
    i) a plurality of stationary electromagnetic transceiving (SET) means;
    ii) a plurality of object-based electromagnetic transceiving (OBET) means; and
    iii) a plurality of network control systems.
11. The communication system as in Claim 10, wherein said plurality of SET means are interconnected through electromagnetic waves to form a cellular network that partitions an area through which said objects will change position.

12. The communication system as in Claim 11, wherein said plurality of OBET means are located on each object that will change position.
13. The communication system as in Claim 12, wherein said open standards-based protocol means throughout the system is a standard internet protocol and wherein the said system monitors the signaling information between said OBET means and said SET means and computes said signaling information to determine characteristics of said OBET means.
14. The communication system as in Claim 13, wherein said characteristics of said OBET means is its spatial location.
15. The communication system as in Claim 10, wherein said plurality of SET means are interconnected by a fiber optic cable.
16. The communication system as in Claim 10, wherein the frequency of said OBET means communicating with said SET means ranges from 2.0 - 2.6 Giga-Hertz (GHz).
17. The communication system as in Claim 16, wherein said frequency is 2.4 GHz.
18. The communication system as in Claim 10, wherein said frequency of said plurality of SET means communicating with one another ranges from 2.0 - 2.6 GHz.
19. The communication system as in Claim 18, wherein said frequency is 2.4 GHz.
20. The communication system as in Claim 10, wherein said SET means and said OBET means employ Slow Frequency Hopping (SFH) spread spectrum techniques.
21. The communication system as in Claim 20, wherein said SET means and said OBET means employ Direct Sequence (DS) spread spectrum techniques.
22. The communication system as in Claim 10, wherein said plurality of SET means and said plurality of OBET means employ a half-duplex Time Division Multiple Access (TDMA) scheme which allows one SET means to communicate with said plurality of OBET means.
23. The communication system as in Claim 10, wherein said plurality of SET means and said plurality of OBET means employ a Code Division Multiple Access (CDMA) scheme which allows one SET means to communicate with said plurality of OBET means.
24. The communication system as in Claim 22 or 23, wherein adjacent SET means employ different SFH patterns that are not synchronized.
25. The communication system as in Claim 24, wherein the frequency hop rate is matched to the length of the TDMA frame.

26. The communication system as in Claim 10, wherein said plurality of network control systems communicates with each other for the coordination and synchronization of said communication system and to facilitate the operation of said communication system.

27. The system as in Claim 26, wherein said plurality of network control systems communicates with a plurality of train service providers to facilitate the operation of said communication system.

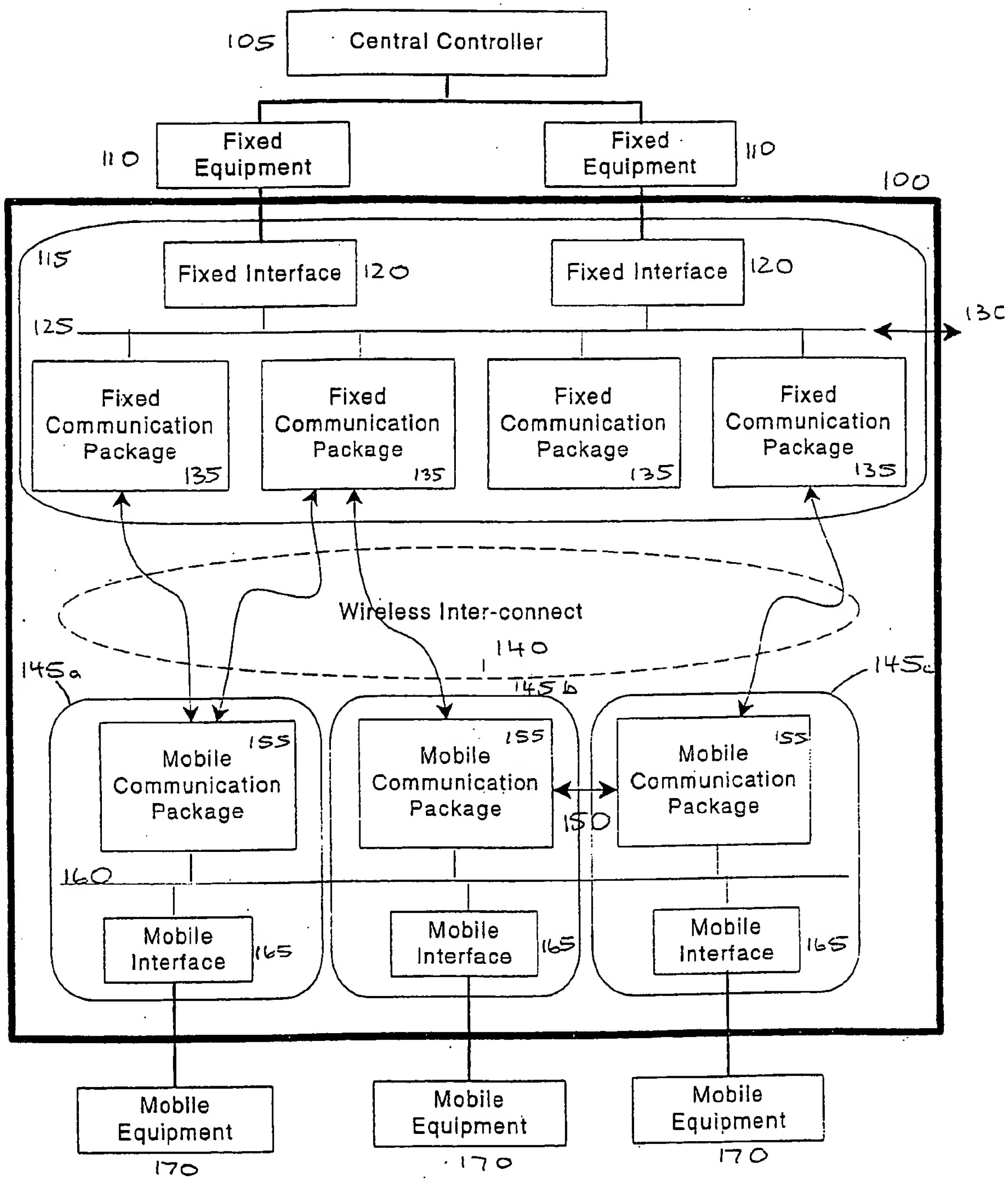
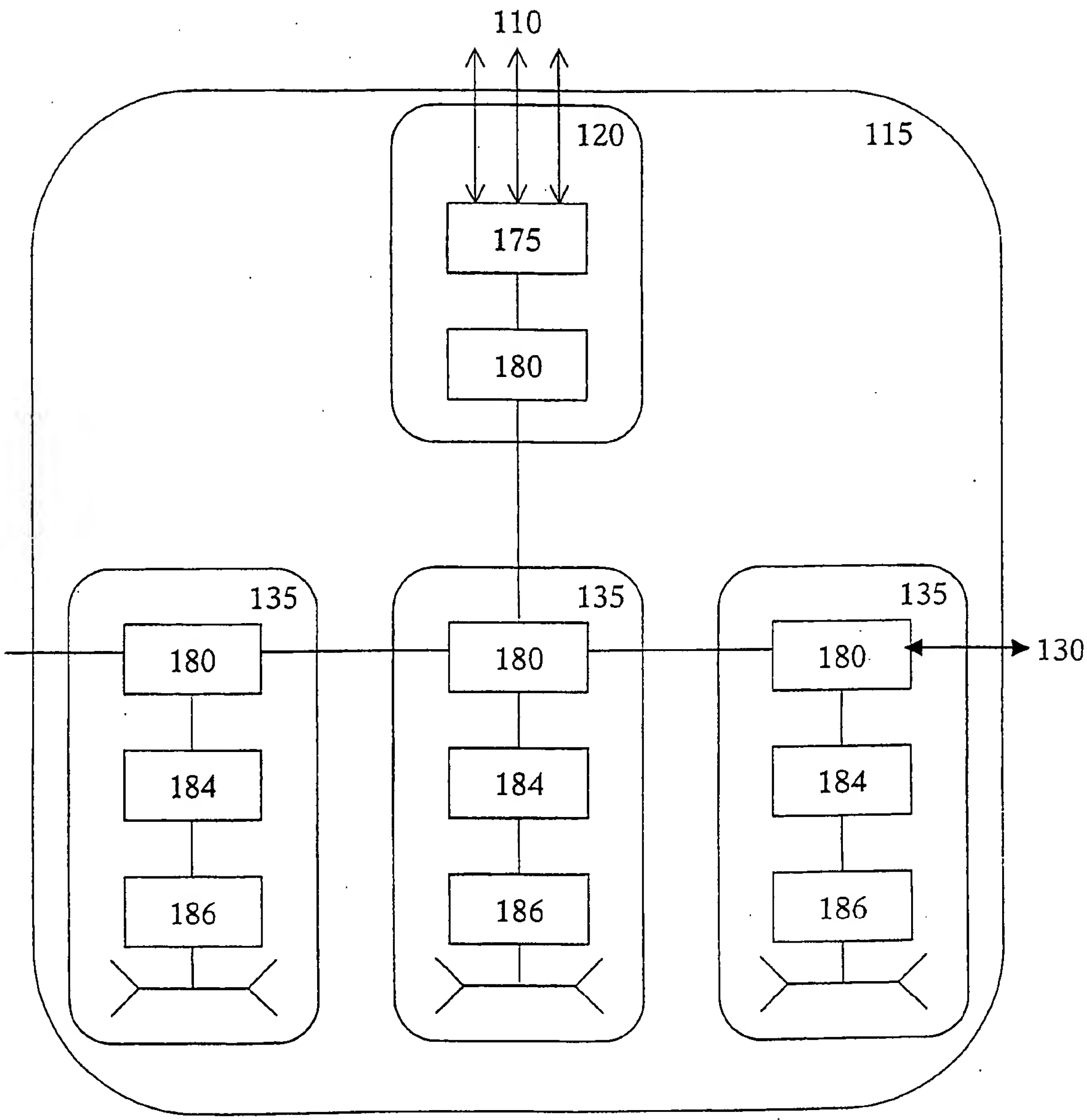
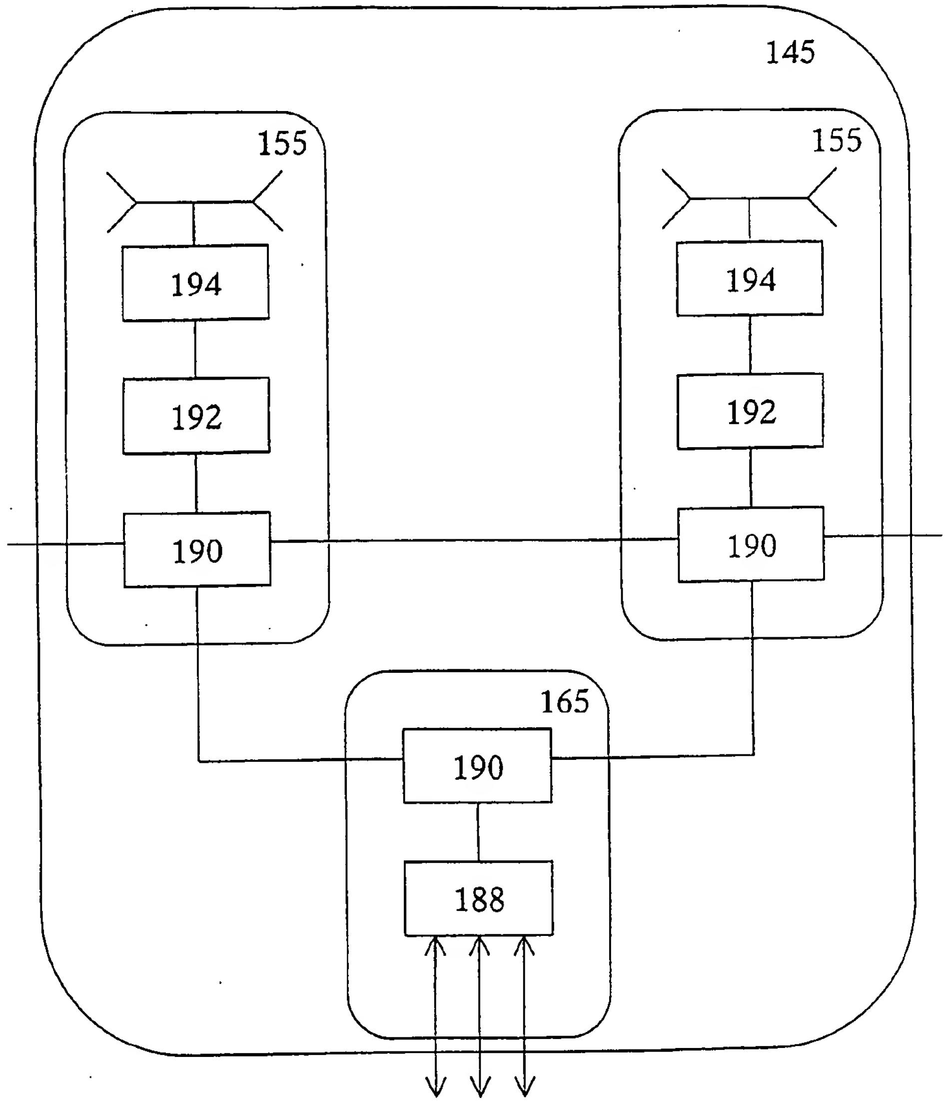

105
Central Controller
Fixed Equipment
110
Fixed Equipment
110
100
115
Fixed Interface
120
Fixed Interface
120
125
130
Fixed Communication Package
135
Fixed Communication Package
135
Fixed Communication Package
135
Fixed Communication Package
135
Wireless Inter-connect
140
145a
145b
145c
Mobile Communication Package
155
Mobile Communication Package
155
Mobile Communication Package
155
150
160
Mobile Interface
165
Mobile Interface
165
Mobile Interface
165
Mobile Equipment
170
Mobile Equipment
170
Mobile Equipment
170

Figure1a



110 fixed equipment
115 fixed network
130 wireless interconnect
175 protocol conversion
180 standard IP router
184 wireless controller
186 wireless modem

Figure 1b



142 mobile network interface
145 mobile network
155 mobile communications package
170 mobile equipment

188 protocol conversion
190 standard IP router
192 wireless controller
194 wireless modem

Figure 1c

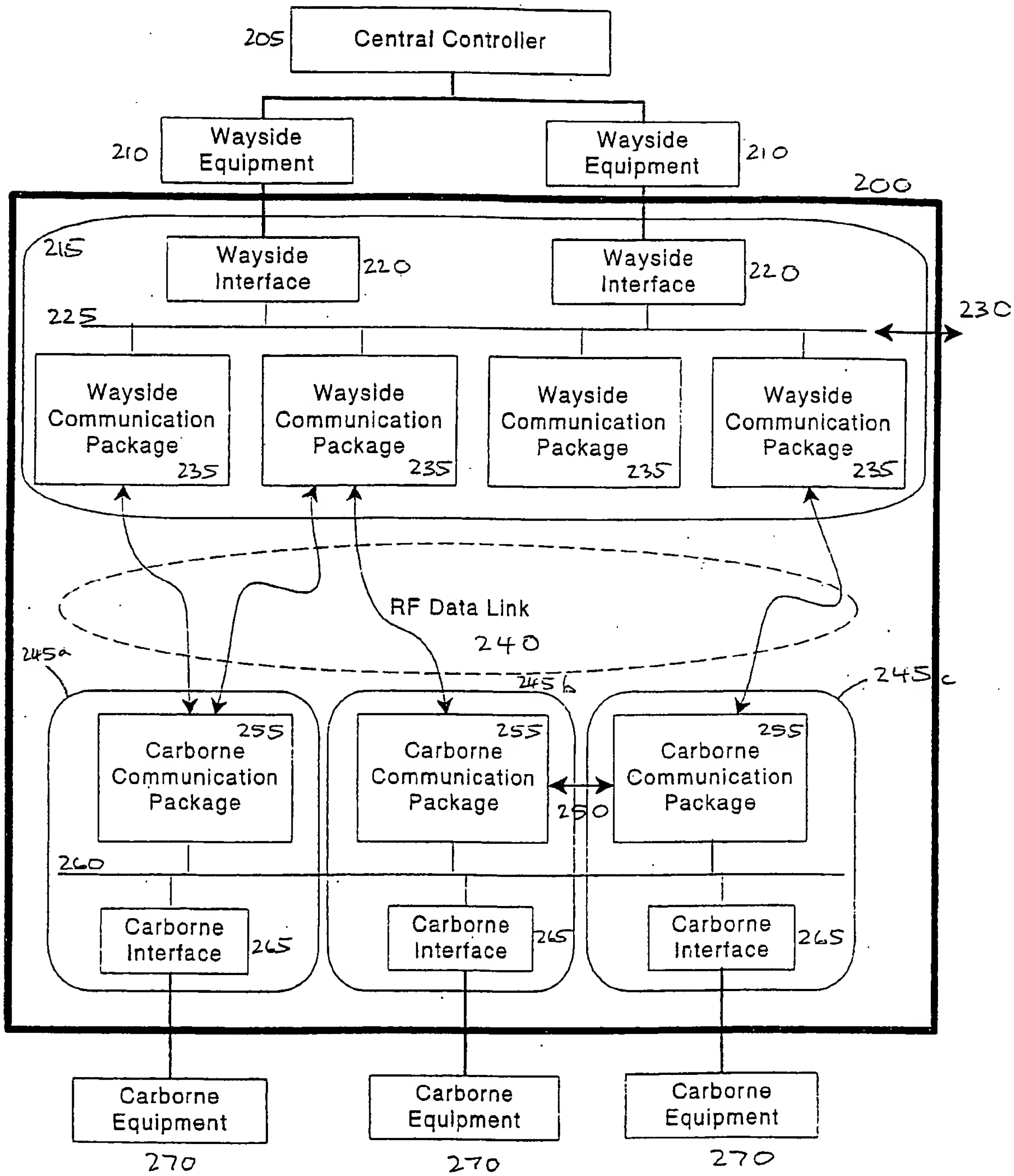

Central Controller
205
Wayside Equipment
210
Wayside Equipment
210
200
215
Wayside Interface
220
Wayside Interface
220
225
230
Wayside Communication Package
235
Wayside Communication Package
235
Wayside Communication Package
235
Wayside Communication Package
235
RF Data Link
240
245a
245b
245c
Carborne Communication Package
255
Carborne Communication Package
255
Carborne Communication Package
255
250
260
Carborne Interface
265
Carborne Interface
265
Carborne Interface
265
Carborne Equipment
270
Carborne Equipment
270
Carborne Equipment
270

Figure 2

Communications System Architecture

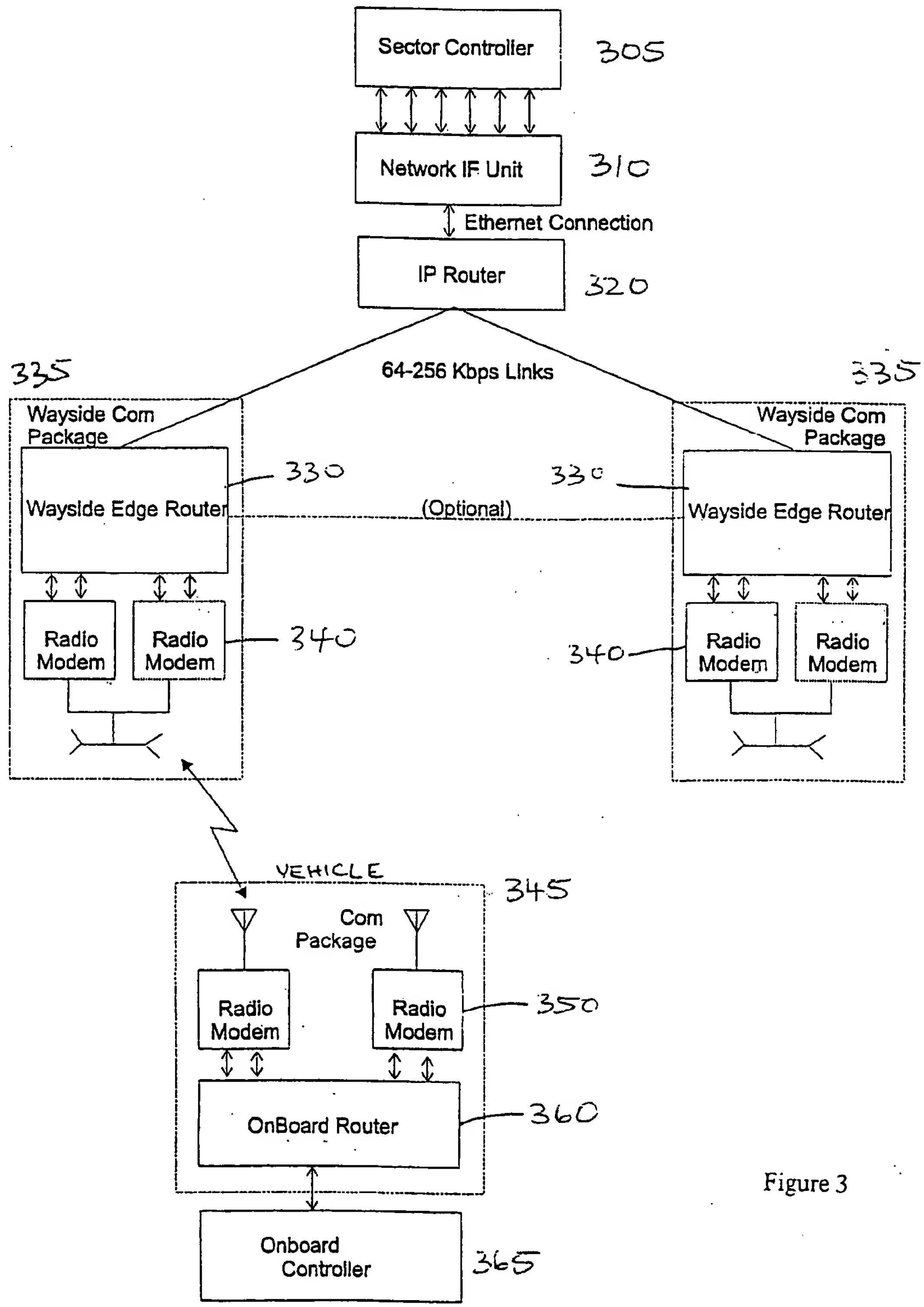


Figure 3

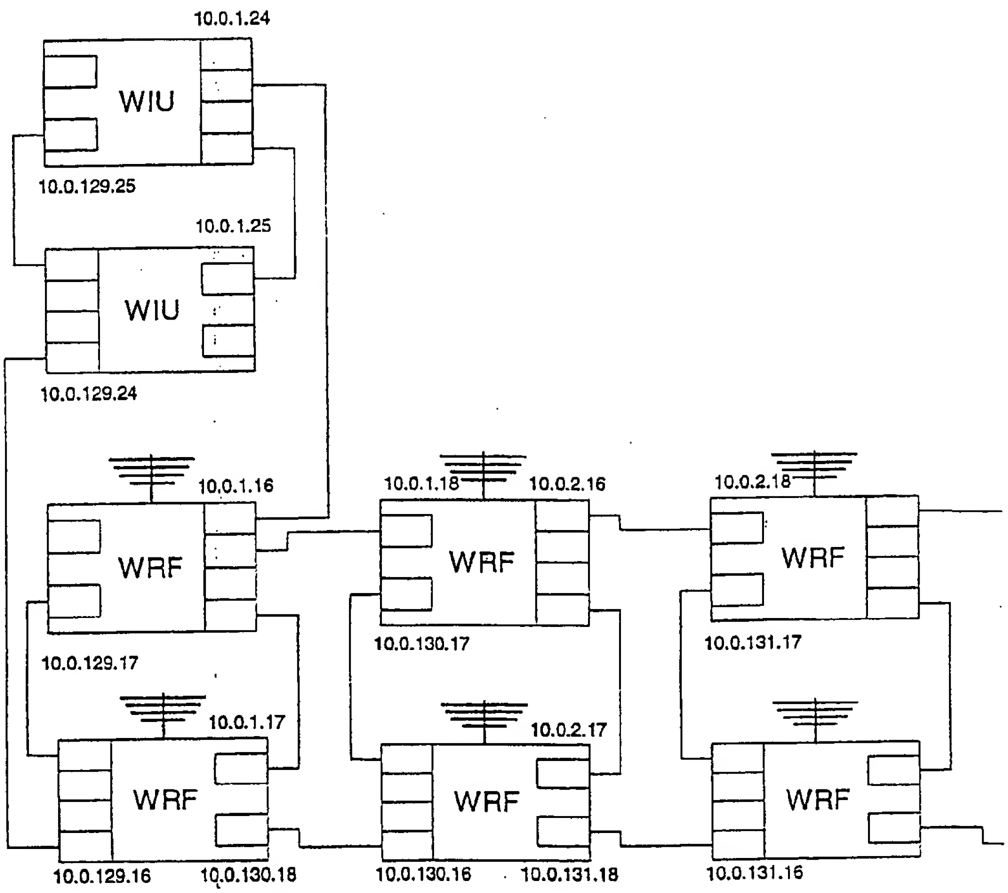

10.0.1.24
WIU
10.0.129.25
10.0.1.25
WIU
10.0.129.24
10.0.1.16
WRF
10.0.129.17
10.0.1.17
WRF
10.0.129.16
10.0.130.18
10.0.1.18
10.0.2.16
WRF
10.0.130.17
10.0.2.17
WRF
10.0.130.16
10.0.131.18
10.0.2.18
WRF
10.0.131.17
WRF
10.0.131.16

Figure 4

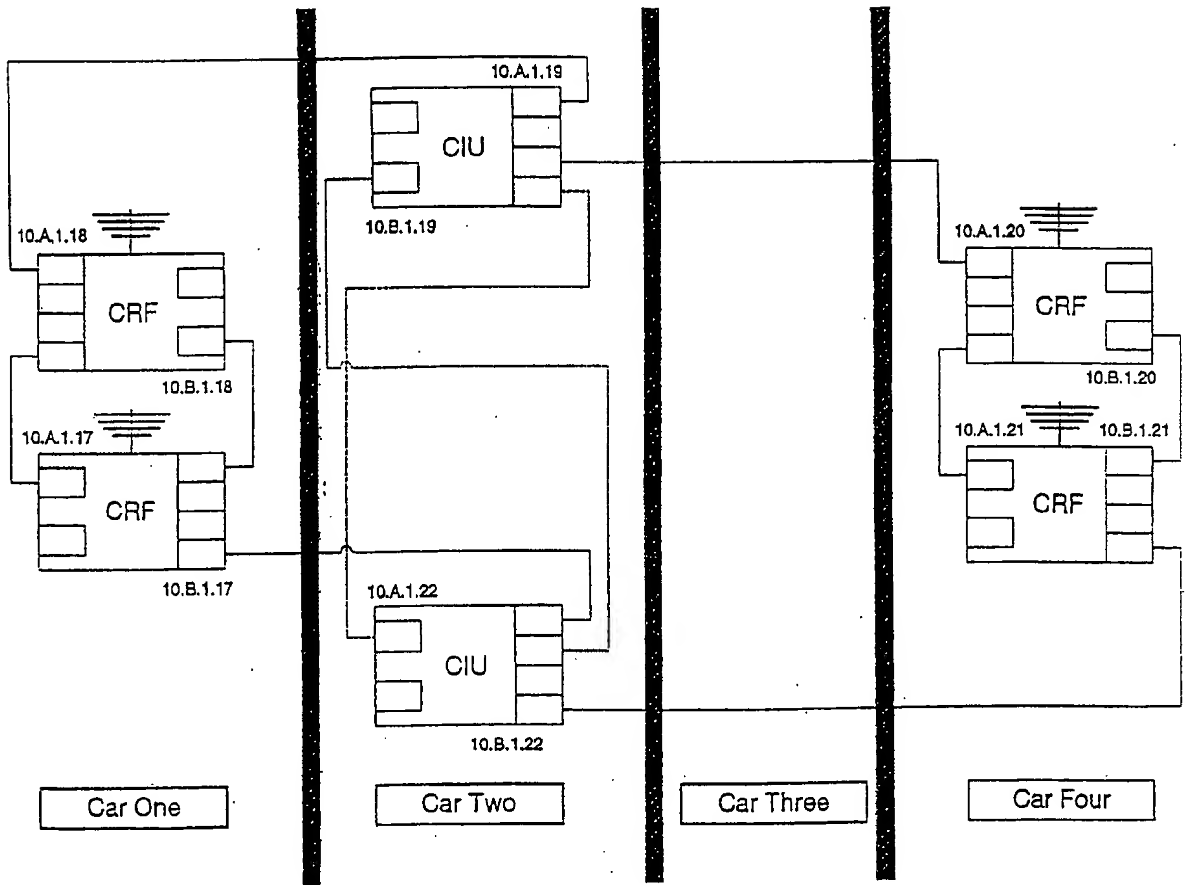

10.A.1.19
CIU
10.B.1.19
10.A.1.18
CRF
10.B.1.18
10.A.1.17
CRF
10.B.1.17
10.A.1.22
CIU
10.B.1.22
10.A.1.20
CRF
10.B.1.20
10.A.1.21
10.B.1.21
CRF
Car One
Car Two
Car Three
Car Four

Figure 5

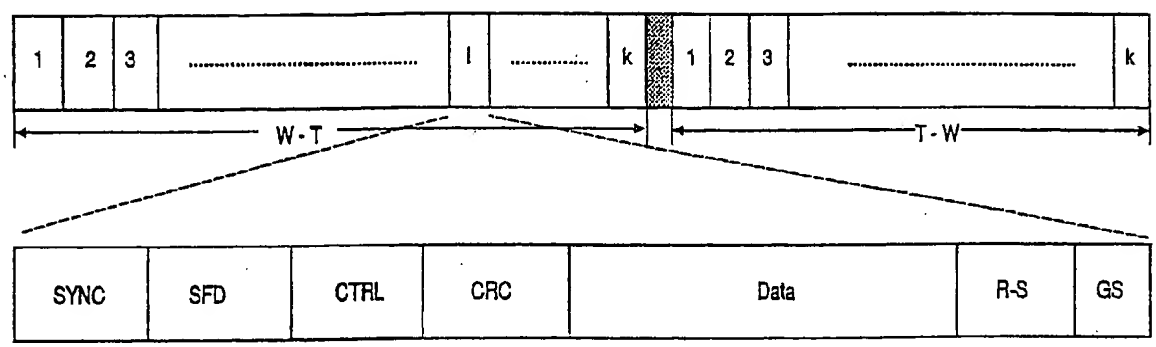


Figure 6

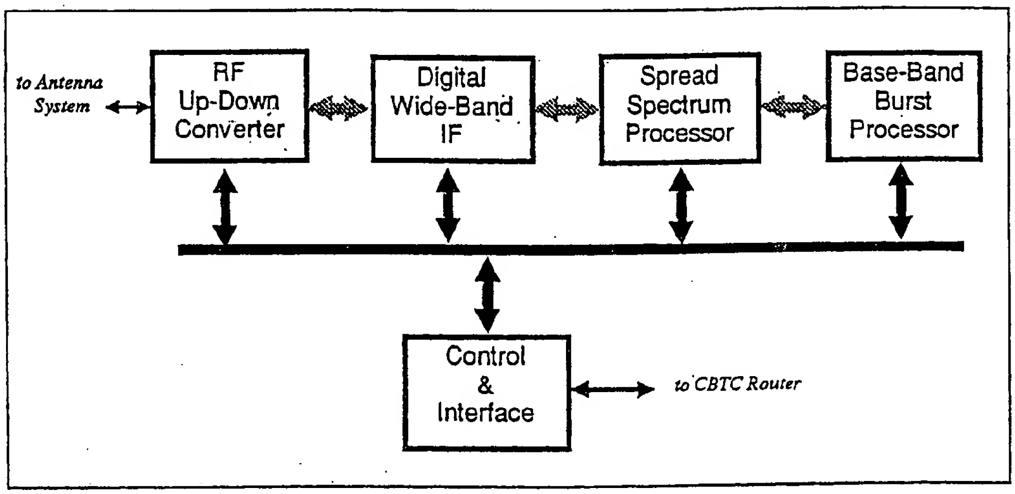

to Antenna System
RF Up-Down Converter
Digital Wide-Band IF
Spread Spectrum Processor
Base-Band Burst Processor
Control & Interface
to CBTC Router

Figure 7

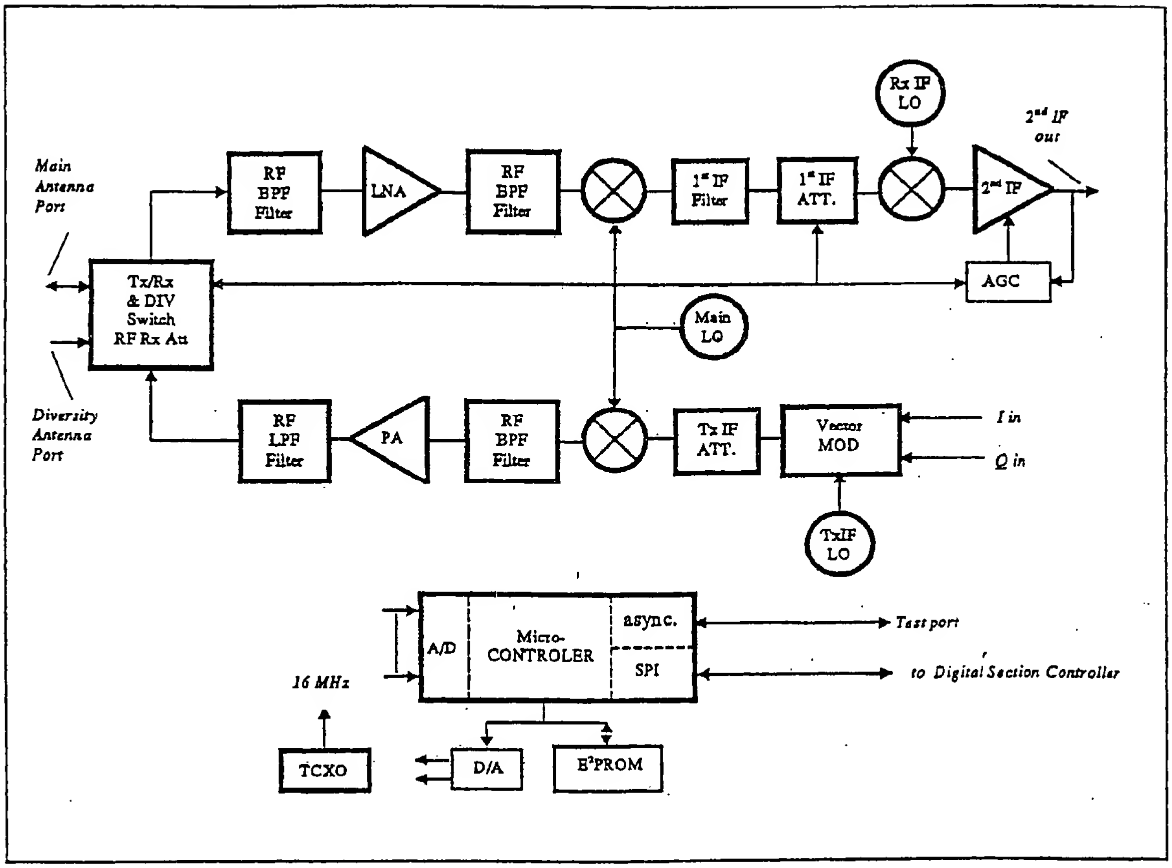

Main Antenna Port
Diversity Antenna Port
Tx/Rx & DIV Switch RF Rx Att
RF BPF Filter
LNA
RF BPF Filter
1st IF Filter
1st IF ATT.
Rx IF LO
2nd IF
2nd IF out
AGC
Main LO
RF LPF Filter
PA
RF BPF Filter
Tx IF ATT.
Vector MOD
I in
Q in
TxIF LO
A/D
Micro-CONTROLER
async.
SPI
Test port
to Digital Section Controller
16 MHz
TCXO
D/A
E²PROM

Figure 8

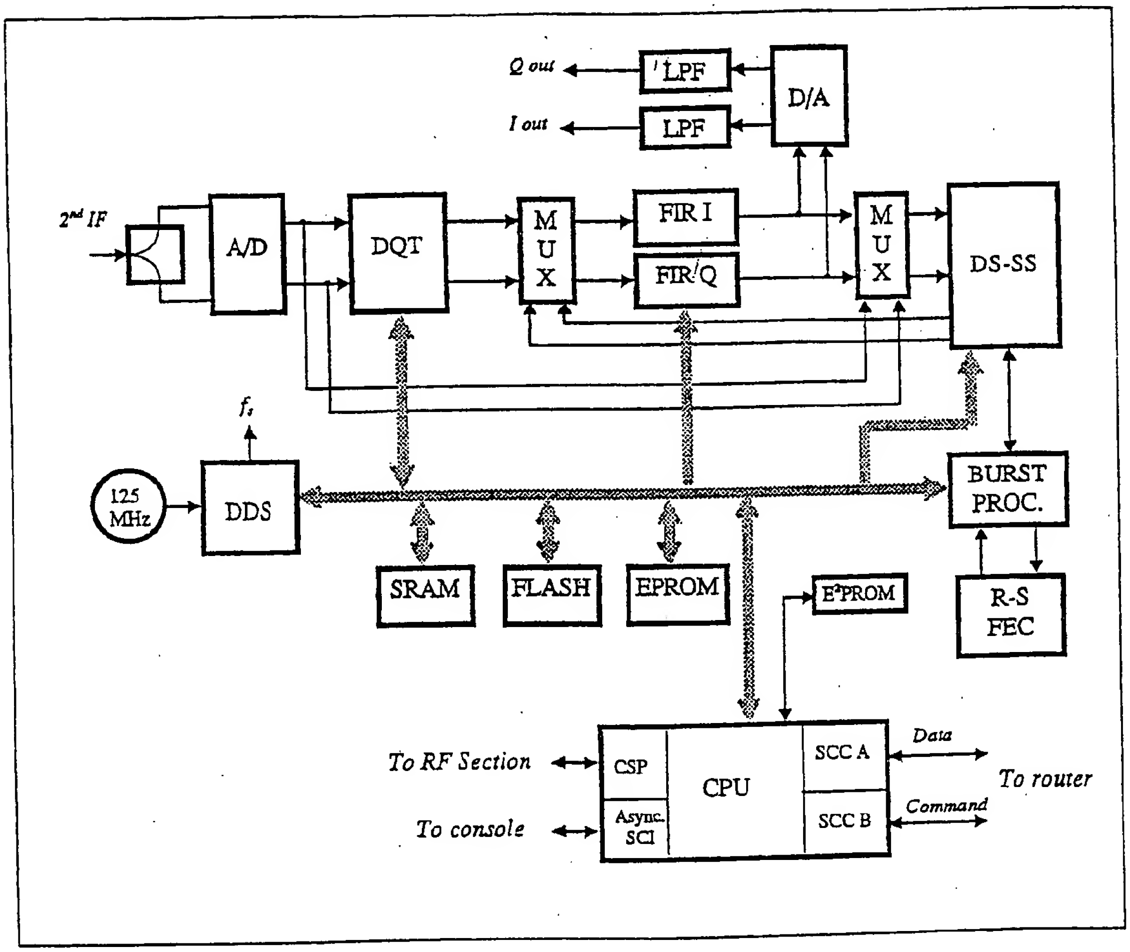

Q out
I out
LPF
LPF
D/A
2nd IF
A/D
DQT
M U X
FIR I
FIR Q
M U X
DS-SS
f_s
125 MHz
DDS
BURST PROC.
SRAM
FLASH
EPROM
E²PROM
R-S FEC
Data
To RF Section
CSP
CPU
SCC A
To router
To console
Async. SCI
SCC B
Command

Figure 9

Hopping Sequence #	Frequency																
1*	16	7	13	15	6	1	5	3	12	2	8	14	4	10	11	9	17
2*	11	15	2	9	6	8	17	1	14	16	5	4	7	3	10	13	12
3*	4	13	2	17	5	10	15	8	16	3	11	6	14	7	12	9	1
4*	9	15	12	10	7	5	14	17	6	2	11	13	3	4	16	1	8
5*	13	5	8	11	7	1	2	10	16	6	12	4	17	15	3	14	9
6*	3	5	1	6	15	13	7	16	17	9	11	10	4	14	8	2	12
7	2	3	1	15	7	17	11	4	8	12	5	6	13	16	9	10	14
8	10	5	17	2	13	4	1	9	12	7	14	6	11	3	16	8	15
9	11	8	5	13	9	14	3	15	17	4	12	6	16	10	2	1	7
10	10	12	15	9	8	1	16	4	3	13	11	2	6	17	14	5	7
11	12	16	2	7	8	13	14	15	4	6	10	1	11	5	9	3	17
12	4	11	17	7	15	1	3	2	14	10	9	16	13	6	5	12	8
13	15	11	12	13	10	3	7	4	5	16	14	1	17	8	6	9	2
14	17	10	8	3	6	7	9	4	2	5	15	16	11	14	12	1	13
15	12	14	11	16	15	5	2	4	9	7	6	3	8	10	17	13	1
16	17	3	9	5	11	1	10	6	4	15	14	13	8	7	2	16	12

* Preferred sequences for adjacent cells

Figure 10

INTERNATIONAL SEARCH REPORT

Inter   nal Application No
PCT/CA 00/00186

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26 H04Q7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 39002 A (GAVRILOVICH CHARLES D) 5 December 1996 (1996-12-05)	1-8
A	abstract page 3, line 30 -page 4, line 11 page 5, line 2 -page 7, line 26 page 9, line 14 -page 10, line 9 figure 1 ---	9-27
X	WO 98 28865 A (ERICSSON TELEFON AB L M ;HALLENSTAAL MAGNUS (SE)) 2 July 1998 (1998-07-02)	1
A	abstract page 2, line 7 - line 30 page 6, line 22 -page 9, line 24 figure 2 --- -/--	2-27

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search	Date of mailing of the international search report
28 June 2000	06/07/2000

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